Airborne Observatory
INVESTIGATORS HANDBOOK

NASA LEARJET AIRBORNE OBSERVATORY

INVESTIGATOR'S HANDBOOK

INTRODUCTION

The National Aeronautics and Space Administration operates a Model 24 Learjet for astronomical, meteorological and geophysical research observations. The Learjet is a six-passenger aircraft with a practical operating range of about 1700 nautical miles, an operating ceiling in excess of 45,000 feet, (13.7 km) and a useful payload of about 1,200 pounds. The aircraft is based at the Ames Research Center, Moffett Field, California and is operated by ARC for scientists whose proposals are deemed suitable and are approved by NASA Headquarters.

The purpose of this handbook is to acquaint potential Investigators with the Learjet and its capabilities, to describe the established procedures for securing approval of missions, and to outline the requirements for equipment design and installation. As new aircraft modifications and procedural changes occur, replacement sheets will be mailed to recipients of the handbook. Hence, the loose-leaf format.

It is important for Investigators to design, stress-analyze, and construct their equipment in accordance with accepted aircraft standards. The reader's attention is called particularly to Section III of this handbook.

Wherever possible, dimensional, weight, volume and pressure data are presented throughout the text using the metric system. However, to be consistant with the aircraft maintenance and operation manuals, parameters which are specific to aircraft performance and airframe measurements are presented using the English system.

From an economic and logistics standpoint, operation of the Learjet from Moffett Field is preferable. When extended range or endurance is important to an experiment, a landing may be made at another airport to refuel before returning to Moffett Field. Strong justification is required for use of other bases for extended operations.

The Learjet Investigator's Handbook has been provided to the Airborne Science Office by Walter V. Sterling, Incorporated.

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SECTION I

AIRCRAFT DATA

1.0 LEARJET AIRCRAFT DATA

The Learjet Model 24 (Figures I-1 and I-2) is a six-passenger, high performance aircraft powered by two General Electric CJ-610-6 jet engines delivering a maximum thrust of 2950 lb each. The aircraft is of all metal construction and is characterized by its T-shaped empennage and permanently-mounted, wing-tip fuel tanks. In normal commercial operation, it can carry two pilots, six passengers, and 240 pounds of luggage up to 1490 nmi at Mach 0.73. The following are descriptions and tables which serve to summarize the aircraft specifications and basic performance parameters.

TABLE I - 1

WEIGHT AND DISTANCE CHARACTERISTICS FOR TAKEOFF AND LANDING

At standard sea level pressure and temperature:

Maximum Gross Takeoff Weight	13,600 lb
Maximum Gross Landing Weight	11,880 lb
Empty Weight	7,400 lb
Maximum Fuel Weight	5,300 lb
Takeoff Distance	3,917 ft
Landing Distance	3,352 ft

The maximum takeoff gross weight may be reduced by such factors as runway length, surface, slope and temperature.

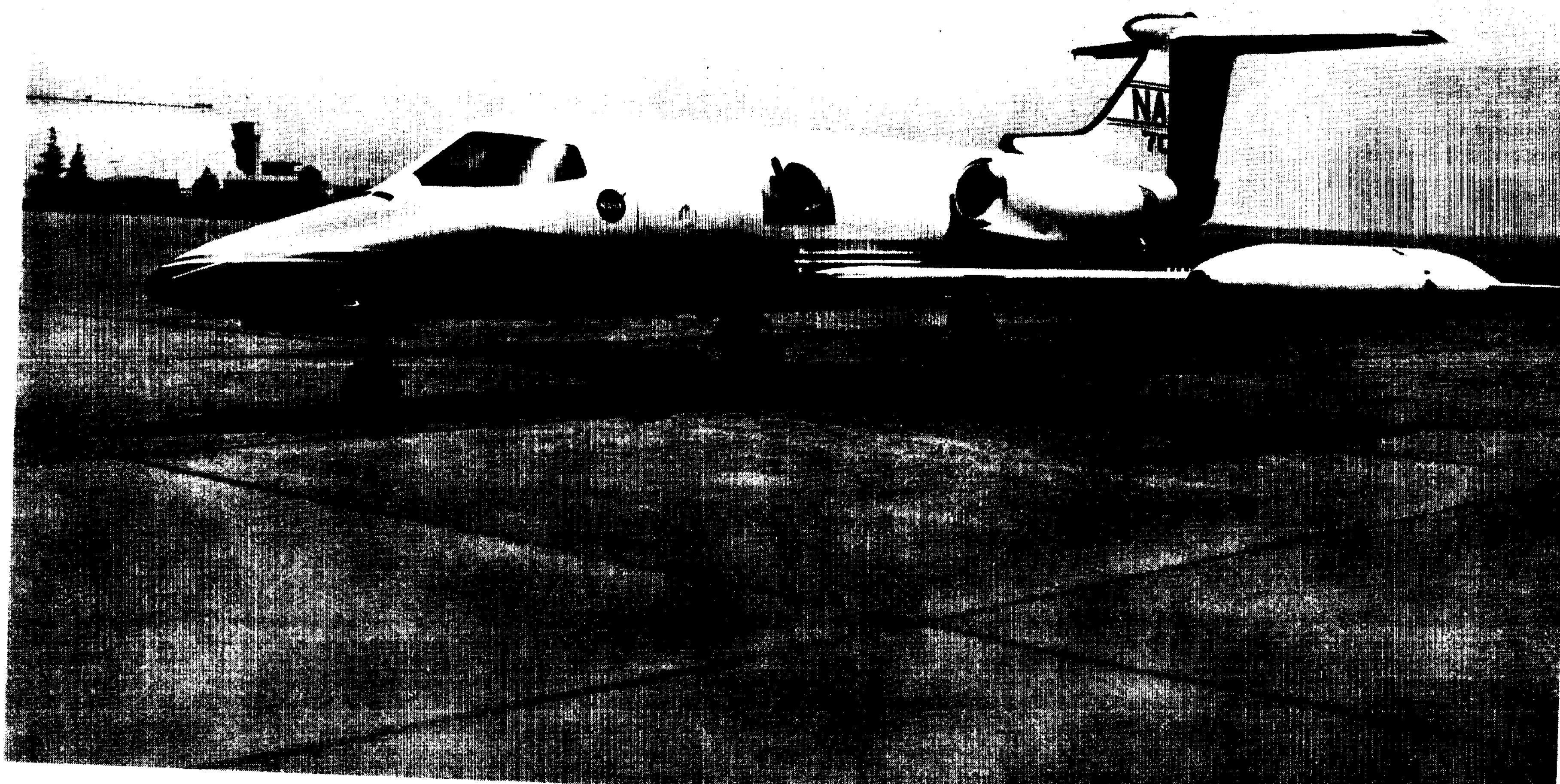

Figure I-1 The Learjet Airborne Observatory

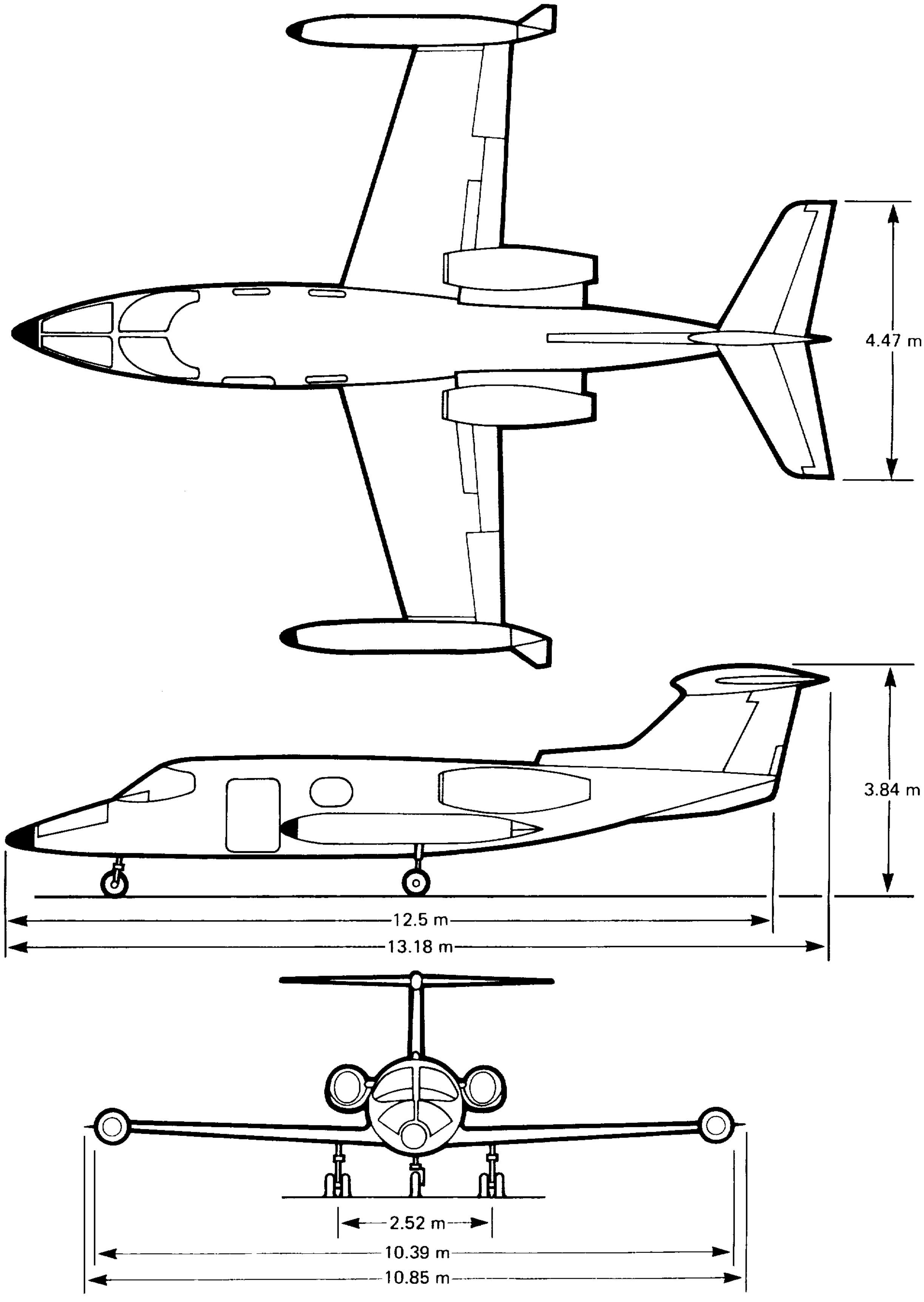

Figure I-2 General View and Overall Dimensions of the Learjet

TABLE I - 2

SPEED-RANGE-TIME ENVELOPE

At an altitude of 45,000 feet (13.7 km), the approximate values of speed, range and block time are:

Mach No.	True Air Speed (kt)	Range (nmi)	Flight Time (hours)	
0.75	430	1290	3:00	(VFR)
0.75	430	1110	2:35	(IFR)

IFR figures take into account a fuel reserve to hold for 45 minutes at 20,000 ft (6 km).

1.1 CRUISE TIME vs GROSS WEIGHT

As illustrated in Figures I-3 and I-4, the altitude attainable in the Learjet is limited by gross weight. These figures give the cruise time and maximum gross weight at various altitudes and the time to climb and fuel consumed for a typical research mission. For example, to reach 45,000 ft (13.7 km) the gross weight must be no greater than 11,600 pounds. With the weight budget given in Table I-1, the engines must consume approximately 1900 pounds of fuel before the aircraft can reach 45,000 ft.

TABLE I - 3

TYPICAL WEIGHT BUDGET FOR AIRBORNE RESEARCH PROGRAMS

Aircraft empty weight (nominal)	7,400 lb	
Two pilots and flight kit	360 lb	
Two Investigators	340 lb	
Two electric power inverters	32 lb	
Investigator's equipment (nominal)	600 lb	
Aircraft zero-fuel weight		8,732 lb
Allowable fuel weight at takeoff	4,868 lb	
Allowable maximum takeoff weight		13,600 lb
Allowable taxi fuel	300 lb	
Maximum allowable ramp weight		13,900 lb

Weight trade-offs can, of course, be made. For example, if only one observer is required, additional experimental equipment can be carried. Also, if range or endurance is not critical, less fuel can be loaded to allow for additional equipment weight. A typical experiment weighs in the range of 181 to 272 kg (400 to 600 lb). See Section IV for operational constraints.

1.2 CABIN PRESSURE

A maximum cabin pressure differential of 8.1 psi is automatically maintained. Table I-4 gives the nominal cabin pressure as a function of aircraft altitude. Cabin pressure differentials can be adjusted by the pilots as necessary. A relief valve is incorporated into the system and is set at 8.3 psi.

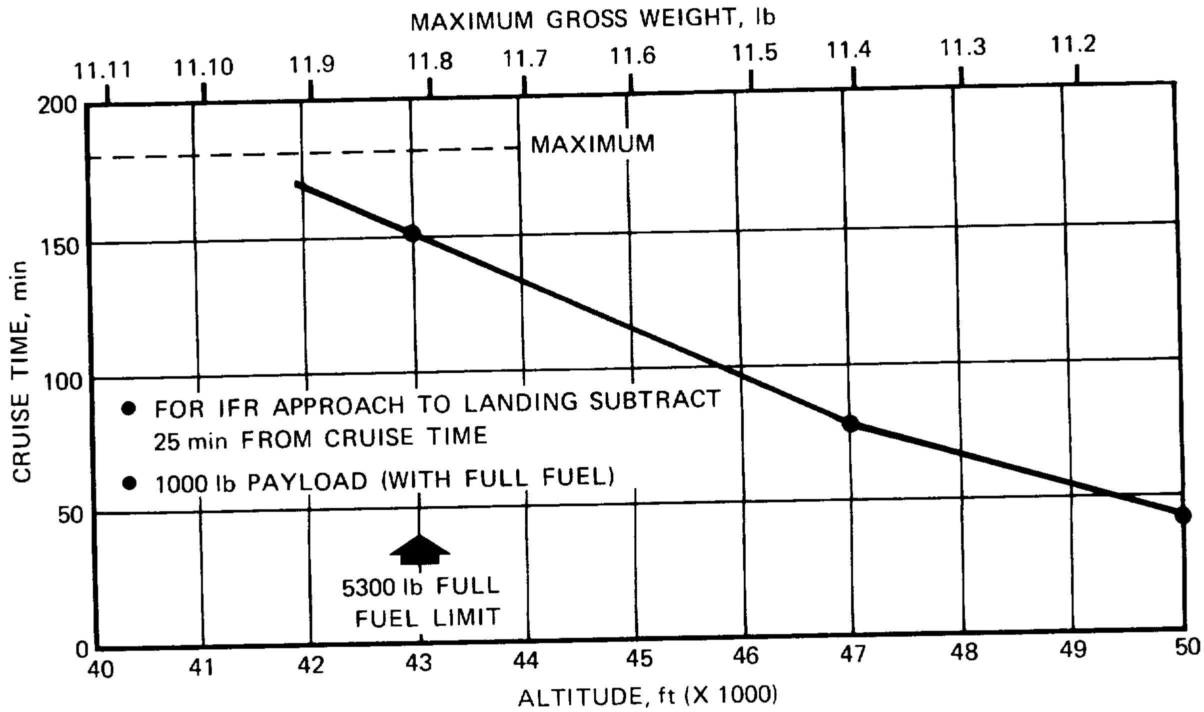

Figure I-3 Cruise Time vs. Altitude for a Typical Learjet Research Flight

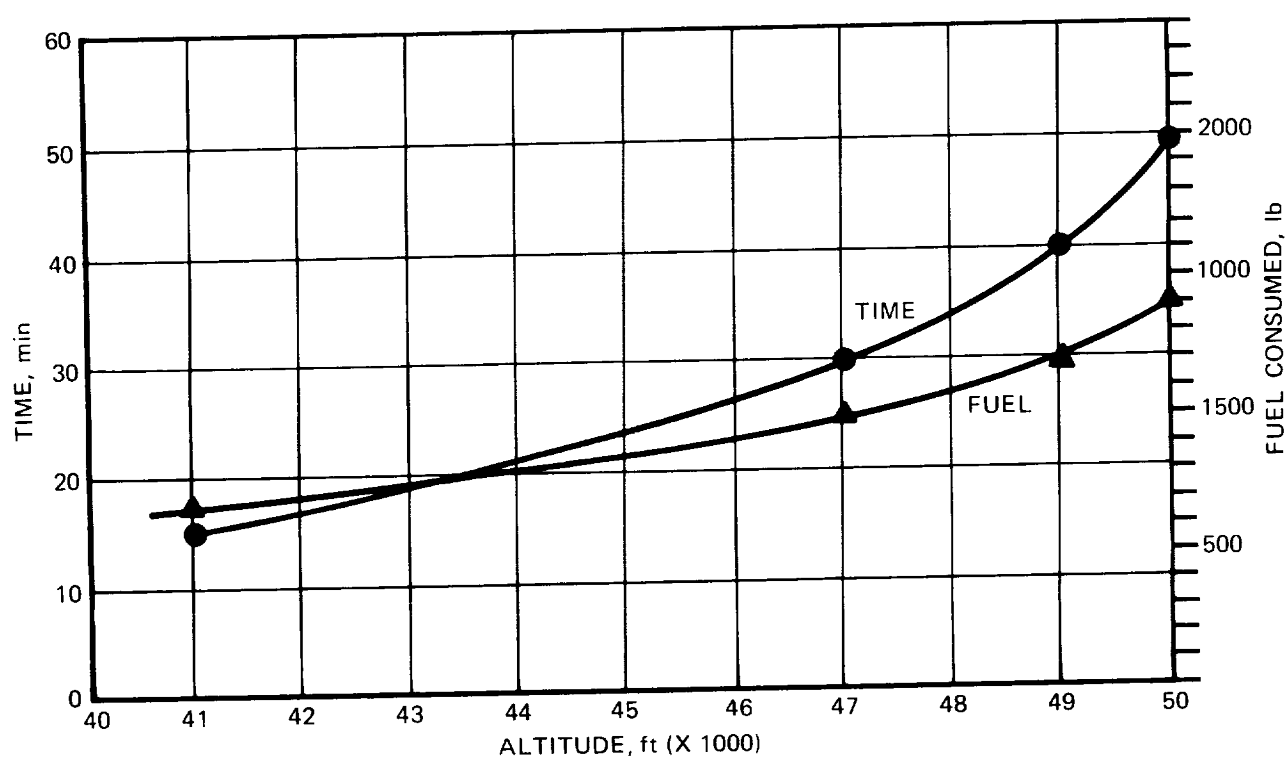

Figure I-4 Maximum Gross Weight Climb Data for a Typical Learjet Research Flight

TABLE I - 4

PRESSURE vs AIRCRAFT ALTITUDE

Aircraft Altitude	Cabin Altitude
46,000 ft (14.0 km)	8,000 ft (2.4 km)
40,000 ft (12.2 km)	6,600 ft (2.0 km)
35,000 ft (10.7 km)	5,000 ft (1.5 km)
25,000 ft (7.6 km)	890 ft (0.3 km)
23,000 ft (7.0 km) and below	Sea Level

For optimum operation of the NASA/Ames 30 cm open-port telescope, a cabin pressure differential of 4.25 ± 0.35 psi must be maintained regardless of altitude. Therefore, for flights above 40,000 ft (12.2 km) the cabin will be maintained at an equivalent of 22,000 ft (6.7 km) altitude. *For these flights, and all flights above 42,000 ft, oxygen masks must be worn by all participants during the entire flight to prevent nitrogen from entering into the bloodstream.*

The cabin temperature can normally be maintained between 18 and 23°C. It is possible to hold the cabin temperature within ± 2°C. However, cabin temperature during high altitude flights using the 30 cm telescope is quite cold. Investigator personnel should wear comfortable, warm clothing during these flights.

1.3 RADIUS AND TIME TO TURN

For some experiments, it is desirable to fly over several closely spaced check points. Since the Learjet is a relatively high speed aircraft, the turn radius can become large. To aid Investigators in planning check points, Table I-5 lists the turn radius and the time to turn 360° for two bank angles at three representative flight speeds. Maximum bank angle at 45,000 ft or above is 15°.

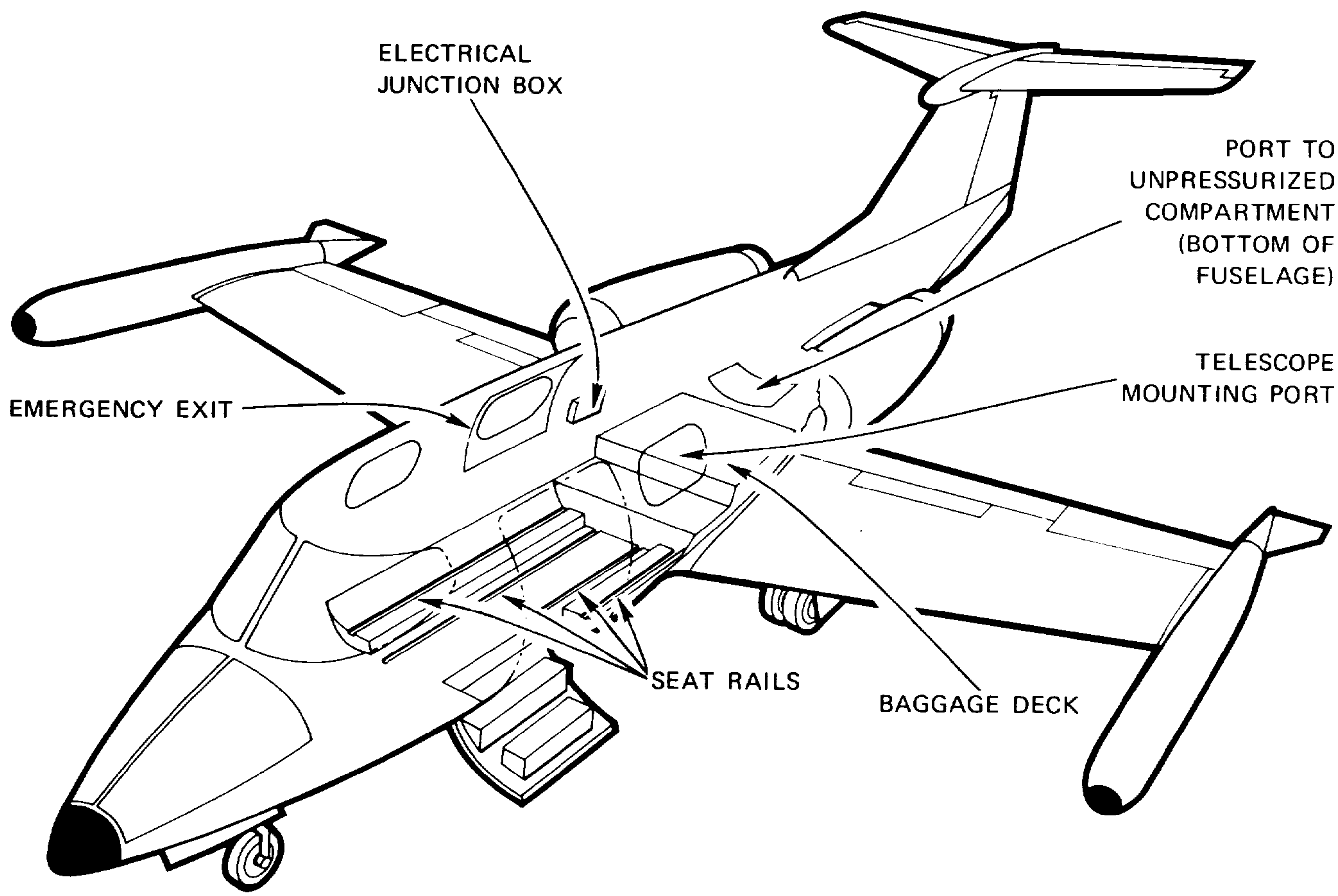

Figure I-5 Learjet Cabin and Baggage Compartment

TABLE I - 5

TURN RADIUS AND TIME TO TURN

True Air Speed (kt)	Bank Angle (deg.)	Turn Radius (nmi)	Time to Turn (min.)
300	15	4.9	6.2
	30	2.3	2.9
400	15	8.7	8.2
	30	4.0	3.8
500	15	13.6	10.2
	30	6.3	4.8

1.4 AIRCRAFT STABILITY

A three-axis autopilot controls the heading and altitude of the Learjet. Nominally, the autopilot can be tuned to limit aircraft excursions in smooth air to better than $\pm$ 1° in pitch, roll, and yaw. Additional platform stability may be obtained with special equipment as described in Section II.

1.5 AIRCRAFT VIBRATION AND ACOUSTIC NOISE

The vibration spectra of the Learjet cabin has been recorded during taxi, takeoff and at cruising altitude. Taxi and takeoff spectra have their major vibrational components below 100 Hz. Although vibrations are generally low in magnitude, resonances can be induced in Investigator's equipment such as interferometer mirrors, detectors, etc. The Investigator is advised to isolate critical components from these vibrations, especially for frequencies below 1000 Hz. Response of components to vibration can be determined at Ames on a vibration table simulating typical

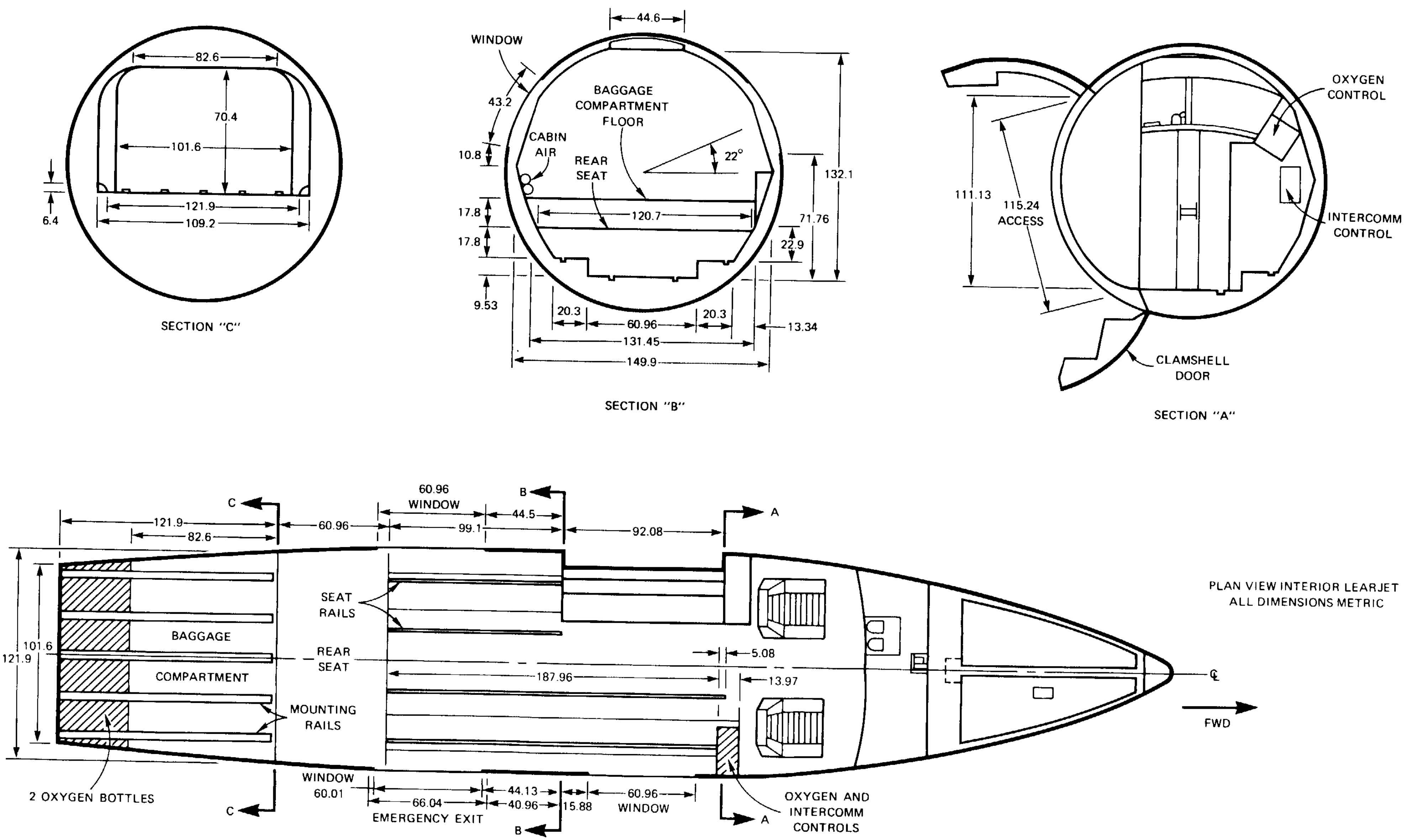

Figure I-6 Cross-section and Plan Views of Learjet Cabin

in-flight vibrational spectra. The Facility Manager should be given sufficient notice of any anticipated use of this equipment.

Another source of vibration must be considered in research employing the 30 cm infrared telescope (Section II). The motion of the secondary mirror in this system is limited by mechanical stops. Impact of the mirror on the stops induces vibrations at chopper frequencies in the telescope and any apparatus attached to the base plate. Thus, sensitive equipment elements attached to the telescope base plate should also be mechanically isolated from this source of vibration.

When cruising at 45,000 ft (13.7 km), the audible sound level at the usual position of the Investigator's electronics rack (forward on the starboard side) is about 80 - 85 dbA. Acoustic noise levels at other cabin locations are of the same order of magnitude.

2.0 RADIO COMMUNICATIONS AND NAVIGATION

The Learjet is equipped with weather radar, very high frequency (VHF), and ultra high frequency (UHF) communications and radio navigation systems. Navigation aids include dual VHF omni-directional range (VOR), dual distance measuring equipment (DME) and low frequency automatic direction finding (ADF). All communication and navigation equipment is set and controlled by the pilots.

The frequency ranges of the various radio equipment are listed in Table I-6. Investigators should design their equipment to prevent spurious response at these frequencies and to limit any output from their systems to less than 100 milliwatts.

The most commonly used communication frequencies are 120.0 through 135.0 MHz.

TABLE I - 6

FREQUENCY RANGES OF LEARJET RADIO EQUIPMENT

Low frequency	0.19 to 1.6 MHz
Marker beacon	75 MHz
Very high frequency	108.0 to 150.8 MHz
Ultra high frequency	225.0 to 500 MHz
Weather radar	9310 and 9775 MHz

2.1 NAVIGATION PLANNING

The Airborne Science Office at the Ames Research Center provides navigation planning and support to accommodate experimental requirements.

ALL DIMENSIONS METRIC

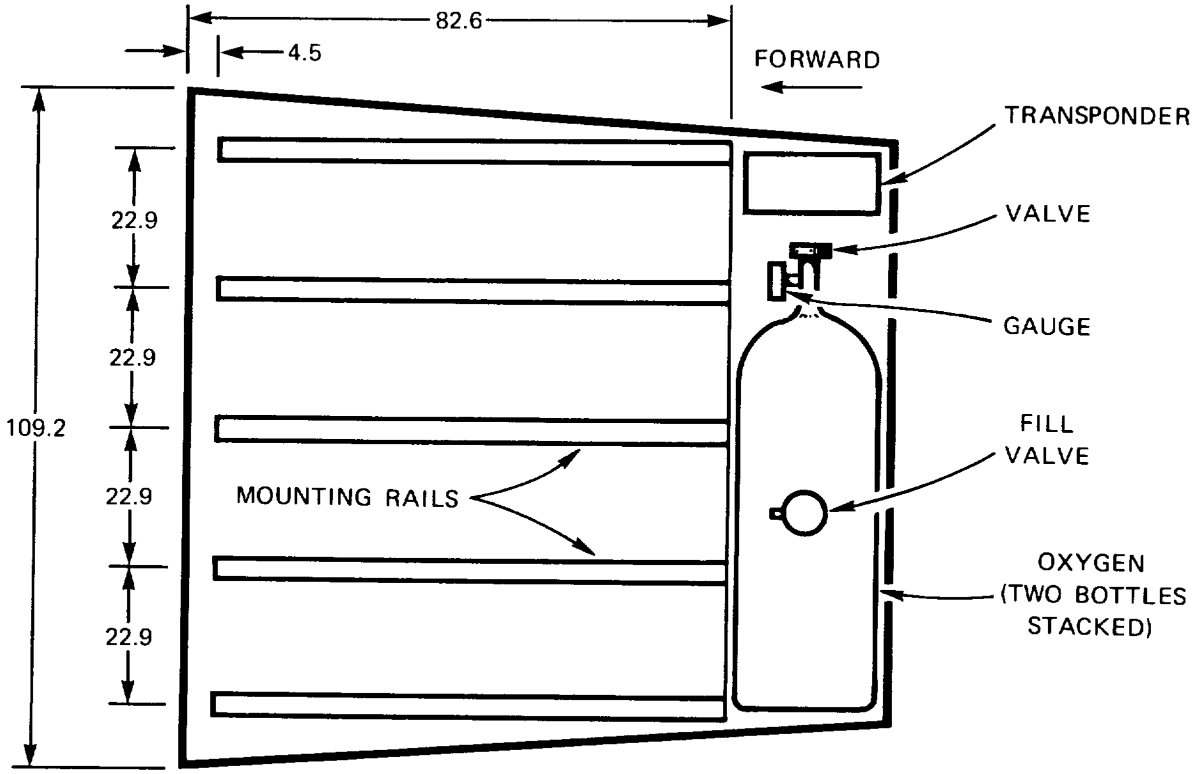

Figure I-7 Baggage Compartment Plan View

ALL DIMENSIONS METRIC

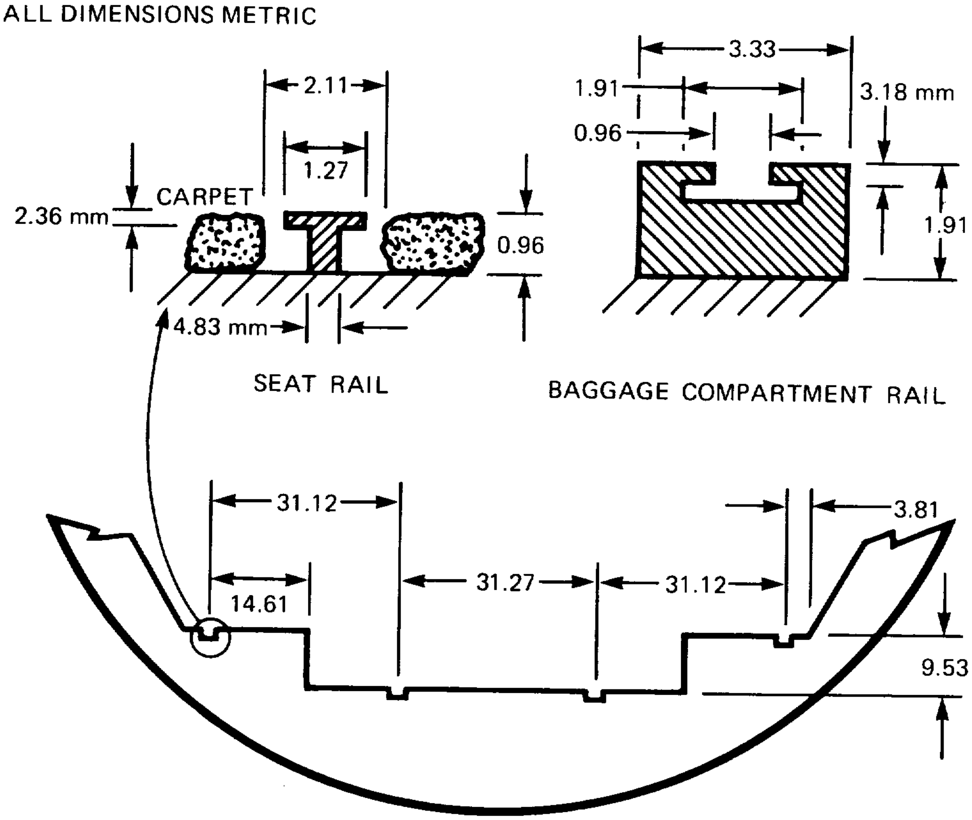

Figure I-8 Seat Rail Spacing and Mounting Rail Cross-Sections

The objects to be observed during astronomical missions should be selected in *advance*. The Investigator should call the Airborne Science Office navigators at least one week in advance of their arrival at Ames Research Center to discuss their flight plans.

2.2 NAVIGATION PROGRAMS

A special computer program is available to provide navigation data (times, headings, etc.) for the observation of any object for which right ascension and declination values are obtainable. The types of flight paths which can be calculated are constant bearing, constant turn rate, great circle, and loxodrome. The program provides object elevation data as a function of time for any of these flight paths. Constant aircraft speed and altitude are assumed and wind corrections are applied by the navigator. Fuel and route to start point are computed by the pilot just prior to flight.

2.3 NAVIGATION ACCURACY

Since the Learjet is a relatively small aircraft, it contains far less navigation equipment than is found in larger jet transports. The primary navigation system is the VOR-DME receiver. The aircraft position can be determined to within 3.7 nmi at the maximum reception distance of 180 nmi.

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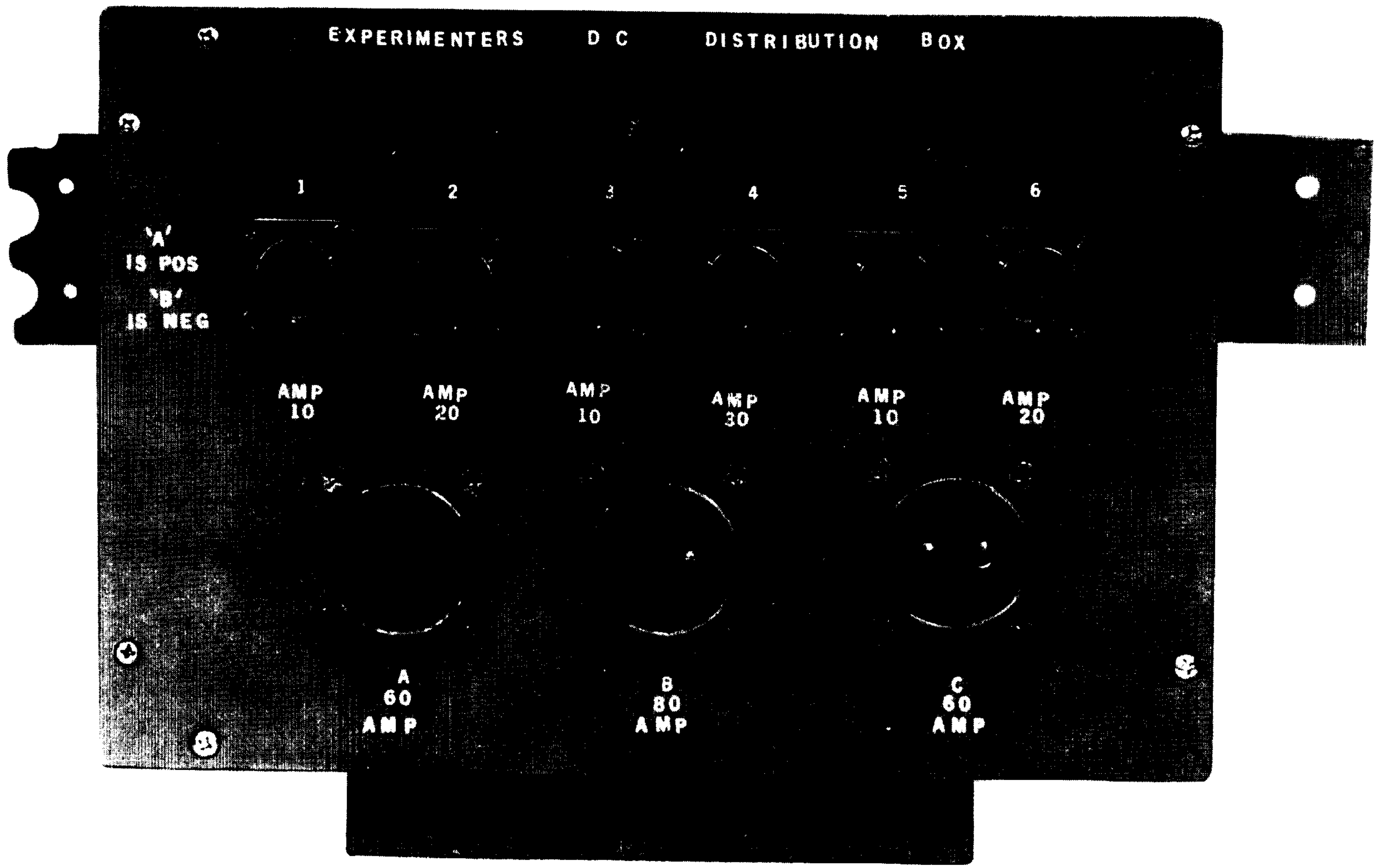

Figure I-9 Investigators DC Distribution Box

3.0 CABIN DIMENSIONS

Figure I-5 gives a perspective view of the Learjet with various ports and pertinent accoutrements identified. Subject to safety considerations and the intrusion of aircraft equipment, the Investigator may mount equipment at any point along the seat rails, on the baggage deck or, in special circumstances, in the unpressurized compartment.

Dimensions of the Learjet interior are given in plan view and a cross section in Figure I-6. Several pieces of aircraft essential equipment encroach upon this space. Two oxygen bottles and a transponder are mounted in the rear of the baggage compartment as shown in Figures I-7 and I-8 reducing the accessible length of mounting rail to 78.1 cm. Equipment mounted in front of the oxygen must allow access to valves and guages on each oxygen bottle. Also encroaching upon the cabin space are two, 5 cm diameter lines which run along the starboard side of the cabin and carry air for cabin pressurization. Oxygen and intercom controls mounted on the forward starboard cabin wall and apparatus mounted below make the space immediately adjacent to this wall of limited usefulness (13 - 15 cm). Finally, the back of the rear seat is inclined toward the rear and extends slightly into the baggage compartment space to a point about 53 cm above the forward ends of the mounting rails.

Access to the baggage compartment is gained by folding the seatback forward to a horizontal position. The back must be secured in the upright position during takeoff and landing.

The details of the seat and baggage compartment mounting rails are given in Figures I-7 and I-8. Fixtures that mate to the rails are available from the Facility Manager.

3.1 FUSELAGE ACCESS DOOR

There is one entrance door located in the forward port side of the cabin (Figure I-5). It is a two-sectioned, clam-shell type door, 92 cm wide and with vertical clearances as defined in Figure I-6. It is equipped with a quick-release mechanism for emergency egress.

4.0 ELECTRICAL POWER

4.1 AIRCRAFT POWER AND INVERTERS

The basic power source consists of two engine-driven 28 VDC generators which can deliver a maximum of 250 amperes each. These generators power two 115 VAC 400 Hz Lear Model SCR 750B inverters. One of these inverters powers the radar, and other aircraft electronic equipment, and the other powers the weather radar when this is required.

4.2 INVESTIGATOR'S POWER

4.2.1 Supply

The source of experiment power is the aircraft 28 VDC supply A maximum of two hundred amperes are available for conversion to 60 or 400 Hz power through use of onboard inverters. These inverters are not carried in the standard weight budget of the aircraft and therefore must be included in the overall weight of the experiment.

Data on the inverters available from the Airborne Science Office are listed in Table I-7. All units deliver 115 VAC ± 5%. Typical power factors (pf) are also given, where known. The power may be drawn in any proportion of 28 VDC, 60 Hz AC and 400 Hz AC so long as the total does not exceed 80% of the available aircraft power. In computing power demand, the Investigator should note that the inverters are only about 70% efficient.

The aircraft 28 VDC power is generated from engine mechanical motion so it has some intrinsic instability. If this is considered excessive for direct current applications, the Airborne Science Office can provide 24 V batteries (NiCd, 22 amp/hr). These batteries weigh 21.8 kg and have dimensions of about 25 X 31 X 17 cm.

NOTE: The weight and volume of the inverters and batteries must be included in the overall weight and volume of the experimental apparatus when considering disposition of the equipment in the aircraft and flight time at altitude.

4.2.2 Power Distribution

The power outlet box for the aircraft 28 VDC supply is located just aft of the escape hatch on the right side of the aircraft. The face of this box is shown in Figure I-9. To match various experimental needs, there are three outlets fused to 10 amp, two at 20 amp, one at 30 amp, two at 60 amp and one at 80 amp. The Facility Manager will supply the proper connectors for interfacing with this outlet box. If AC power is required, the Facility Manager

TABLE I - 7

INVERTER DATA

MODEL	FREQUENCY (Hz)	OUTPUT (VA)	WEIGHT (kg)	WIDTH (cm)	LENGTH (cm)	HEIGHT (cm)	NO. IN STOCK
Flight-tronic PC-17-A	400	750 VA pf 0.8 - 0.95	7.35	21.6	30.5	10.3	2
Topaz 1000 GCWD	60 ± 0.6	1000 VA	86.2*	56.5*	45.7*	67.3*	1
Flight-tronic PC-16**	60 ± 1	250 VA pf 0.8 - 1.0	7.12	19.1	30.5	10.2	4
Accu-Pac	60 ± 1	200 VA	38.6	30.5	61.0	33.0	1

* Weight and dimensions are for the actual inverter including the necessary input filters and the rack in which they are mounted.

**Can be operated synchronously in parallel.

will supply the inverter and will bring the power to the Investigator's rack. An outlet box will be placed on or near the Investigator's rack and will accept up to fourteen standard three-prong male power plugs *which must be used on all Investigator equipment.* The inverters will normally be installed in the rear of the baggage compartment.

Fuses in the 28 VDC circuits are not accessible in flight. Therefore, the Investigator's electrical apparatus *must* be fused realistically so that one of the main aircraft fuses will not be blown in flight. Should this happen, a portion of the experiment would go unpowered for the remainder of the flight or the mission aborted at the discretion of the Aircraft Commander.

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S E C T I O N II

OBSERVING SYSTEMS

1.0 GYROSTABILIZED DEVICES

1.1 ATHWARTSHIP INFRARED TELESCOPE

A 30 cm clear aperture gyro-stabilized open-port telescope is available for use by Investigators. The telescope is approximately f/5 with a maximum field of view of 5 arc minutes. It is equipped with a guide telescope that has a 6 - 7 degree field of view. An altazimuth mount provides vertical and horizontal motion. Motion about the altazimuth mount is gyro-stabilized and motion is ± 3° before encountering the stops. To allow greater elevation flexibility, vertical motion can be augmented by rotation of the whole telescope housing about an axis near the open port. An additional ± 3° of elevation (about the mean of 22°) can be introduced. This adjustment can be made in flight through a turn-buckle arrangement attaching the telescope base to the aircraft floor. The total of about ± 6° vertical motion allows viewing periods of up to the maximum Learjet cruise time on a given object depending on its declination angle and the aircraft heading.

1.1.1 Telescope Power, Weight, and Balance

The telescope system requires 40 amps from the aircraft 28 VDC supply. Thus, 160 amps remain for use by other systems.

The weight of the basic telescope system, without the optics and detector which are to be mounted on the base plate, is 134 kg. This must be included in the overall weight of the experiment when time and altitude are being considered.

If telescope balance is to be achieved without modification to the system, the moment about the roll axis of the apparatus attached to the base plate cannot exceed 3.77 kg/m. The moment arm to be used in this calculation is 10.2 cm plus the distance from the base plate to the center of gravity of the instrument attached to it.

1.1.2 Optical System

The 30 cm infrared telescope employs Dall-Kirkham optics. Eccentricity of the ellipsoidal primary mirror is 0.8; the secondaries are spherical. Other optical constants of the system are listed in Table II-1. A choice both in radius of curvature of the secondary mirror and in the primary-secondary separation (Z_S) allows some freedom both in locating the Cassegrain focal plane, and in experiment design. Coarse variation in Z_S is achieved by mounting the secondary support on the telescope barrel extension rings of various axial thicknesses. Fine control on Z_S is provided by a

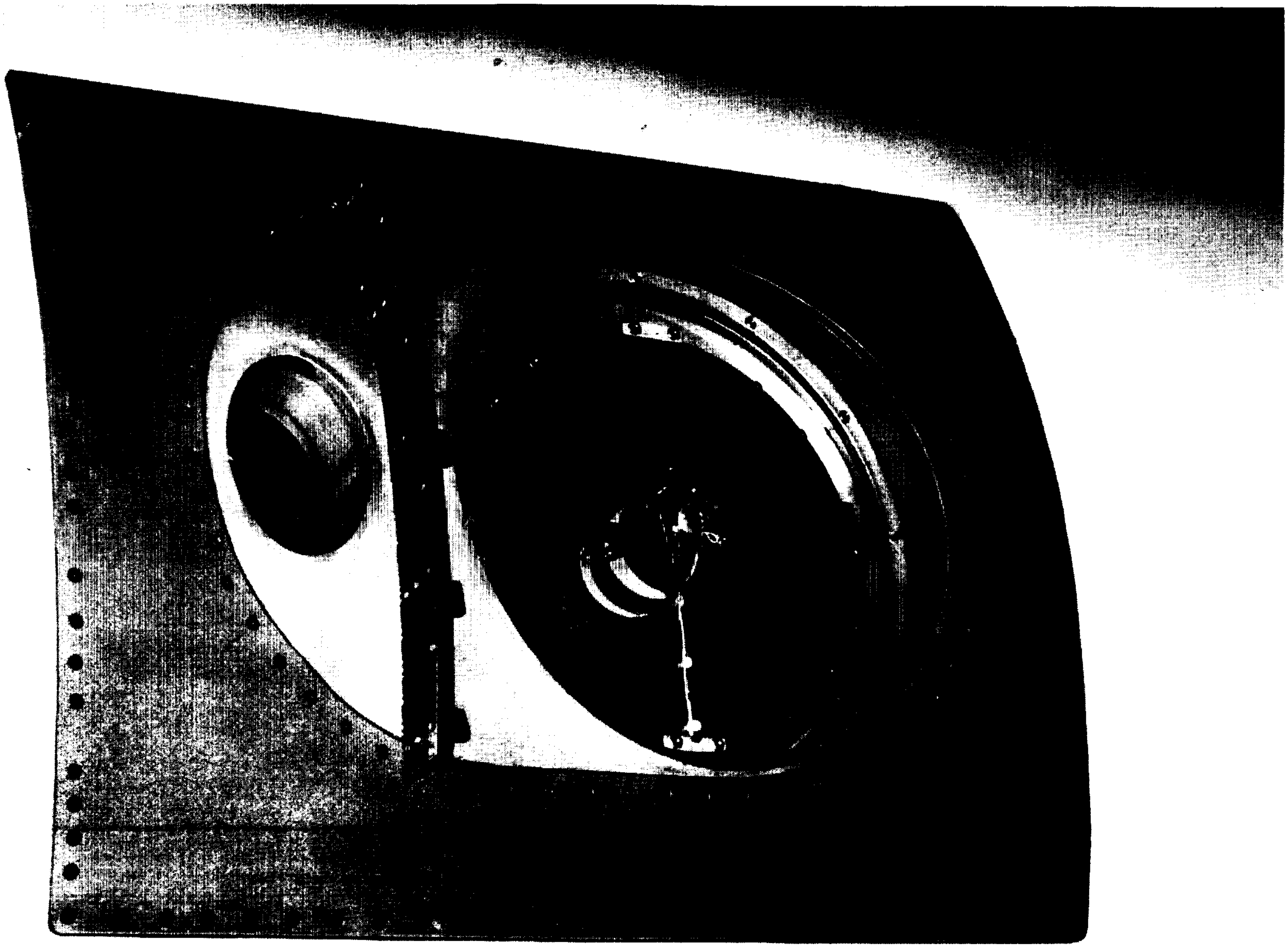

Figure II-1 30 cm Infrared Telescope — External View

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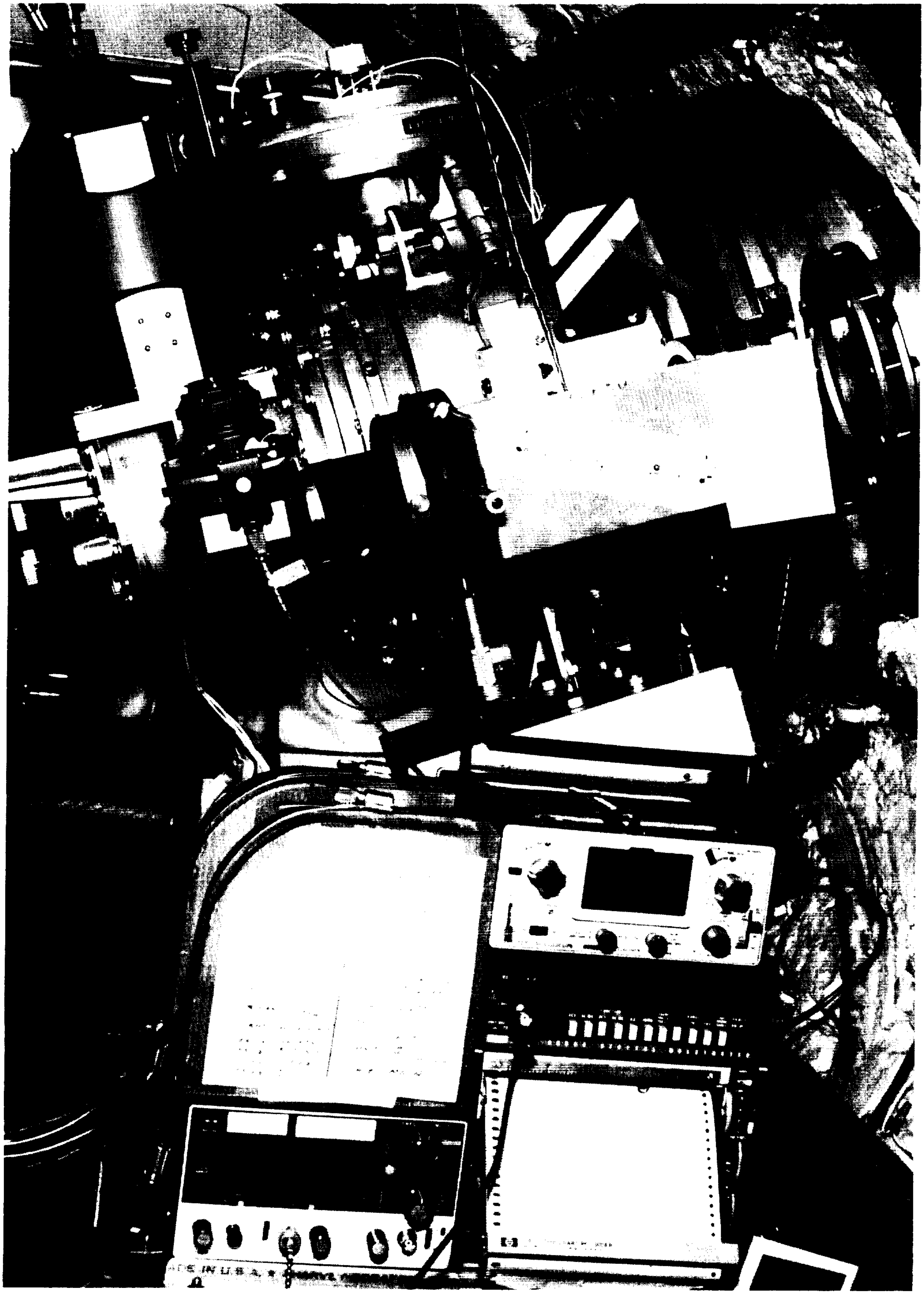

Figure II-2 30 cm Infrared Telescope Installation threaded coupling between the secondary mirror and the support structure. This control allows approximately ± 6 mm of axial motion from the nominal Z_S values listed in Table II-1. The flexibility of the secondary mirror permits positioning the focal plane between about 5 and 35 cm behind the base plate of the telescope. Placing the focal plane outside these limits will require the construction of an appropriate secondary mirror. All reflecting surfaces are aluminum.

1.1.3 Mechanical Interface

The base plate of the telescope is as shown in Figures II-3 and II-4. Two rings of bolt holes are available for attaching equipment to the plate. In designing equipment to be mounted on this plate, all bolt holes in the hole circle used must be utilized. Also, the center of gravity of the instrument should be kept as close as possible to the base plate.

1.1.4 Control Electronics

The panel faces of the two principal pieces of telescope control electronics are shown in Figures II-6 and II-7. The gyro electronics weigh 23 kg and are usually mounted on a low rack just forward of the telescope adjacent to the passenger entrance. The chopper and voltage-to-frequency converter weigh 8 kg and are generally mounted in the Investigator's electronic rack. Investigator electronics and equipment can be mounted in three locations: the low platform rack, the standard Investigator's rack, and in the baggage compartment.

1.1.5 Operating Instructions

The Airborne Science Office has detailed instructions for adjusting the secondary mirror throw and operation of the stabilization and telescope control electronics. This information is available on request. A member of the Ames Research Center Infrared Astronomy Group is also available for personal consultation in the use of the telescope system.

Figure II-8 gives a plan view and a section of a typical infrared astronomy installation. Typical utilization of cabin space during observation is demonstrated in Figure II-9.

TABLE II - 1

OPTICAL CONSTANTS FOR THE ARC 30 CM TELESCOPE

SYSTEM ELEMENT	FOCAL LENGTH	DIAMETER	MAXIMUM THICKNESS	CONSTRUCTION MATERIAL
Primary Mirror	46.48 cm*	30.48 cm		
Secondary Mirror	14.99 cm**	7.87 cm	0.43 cm	Cervit
Secondary Mirror	16.26 cm**	7.87 cm	0.71 cm	Silicon
Secondary Mirror	18.54 cm**	7.87 cm	0.41 cm	Cervit

AXIAL DIMENSIONS

Obtainable Primary to Secondary (Z_s) Distances	38.10 cm 38.71 cm 39.19 cm 39.80 cm
Effective Base Plate Thickness (Primary Mirror Plus Base Plate)	3.51 cm
Radius for Secondary Motion	2.01 cm

* Measured spherical equivalent; from position where object distance equals image distance.

**Calculated from radius of curvature.

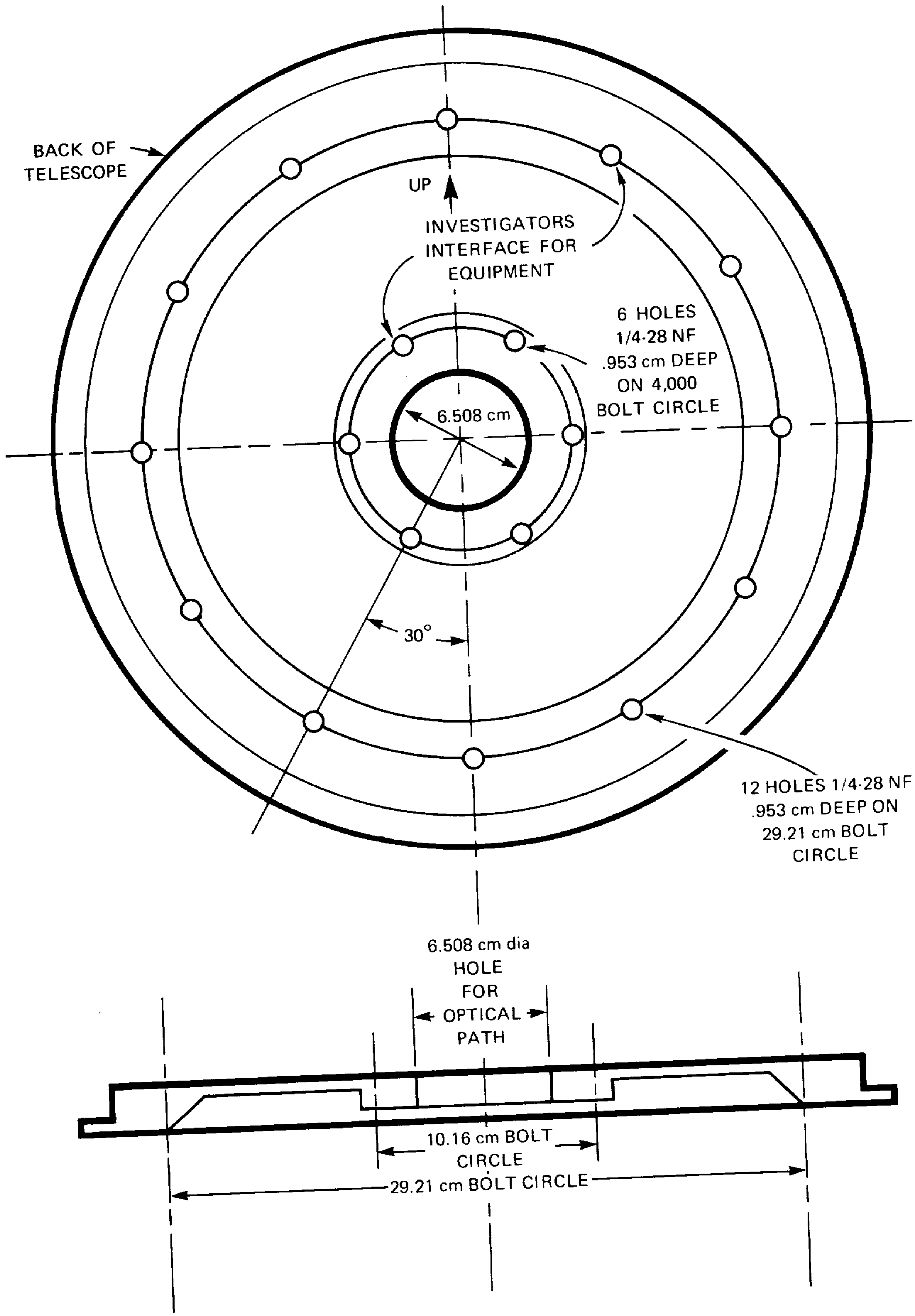

Figure II-3 Investigators Interface to Telescope Base

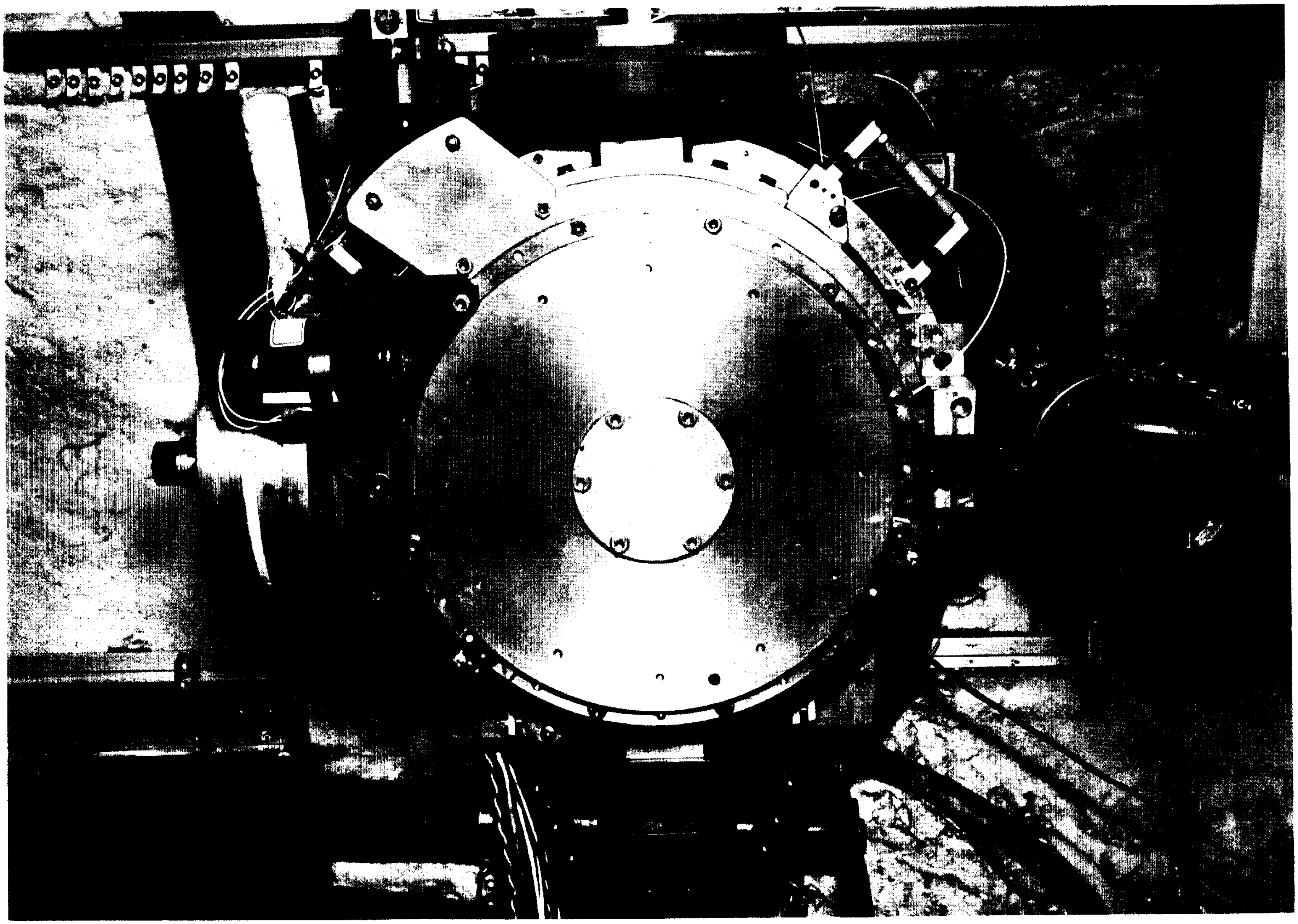

Figure II-4 30 cm Infrared Telescope Base

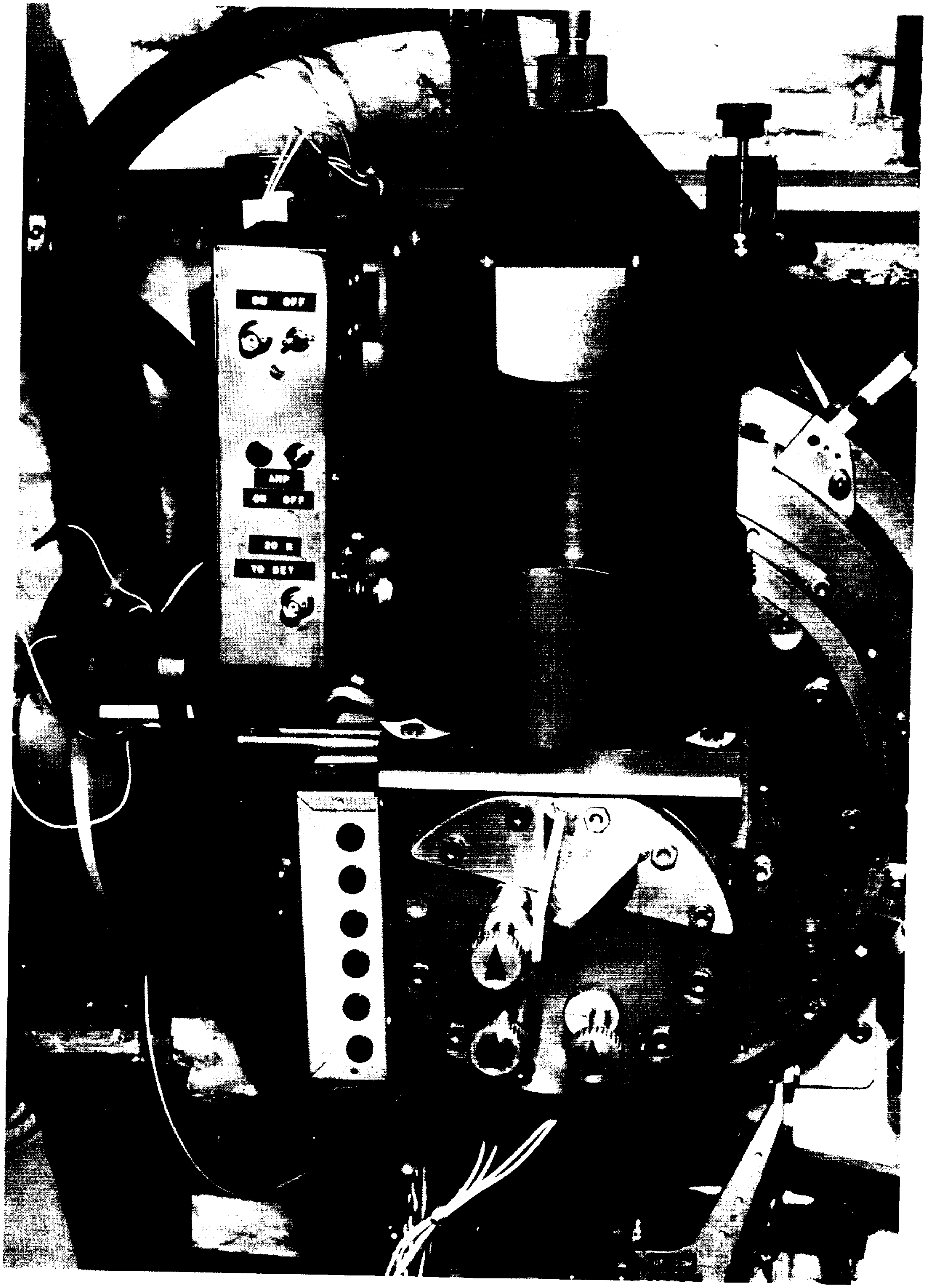

Figure II-5 30 cm Infrared Telescope with Investigator Equipment Installed (Typical)

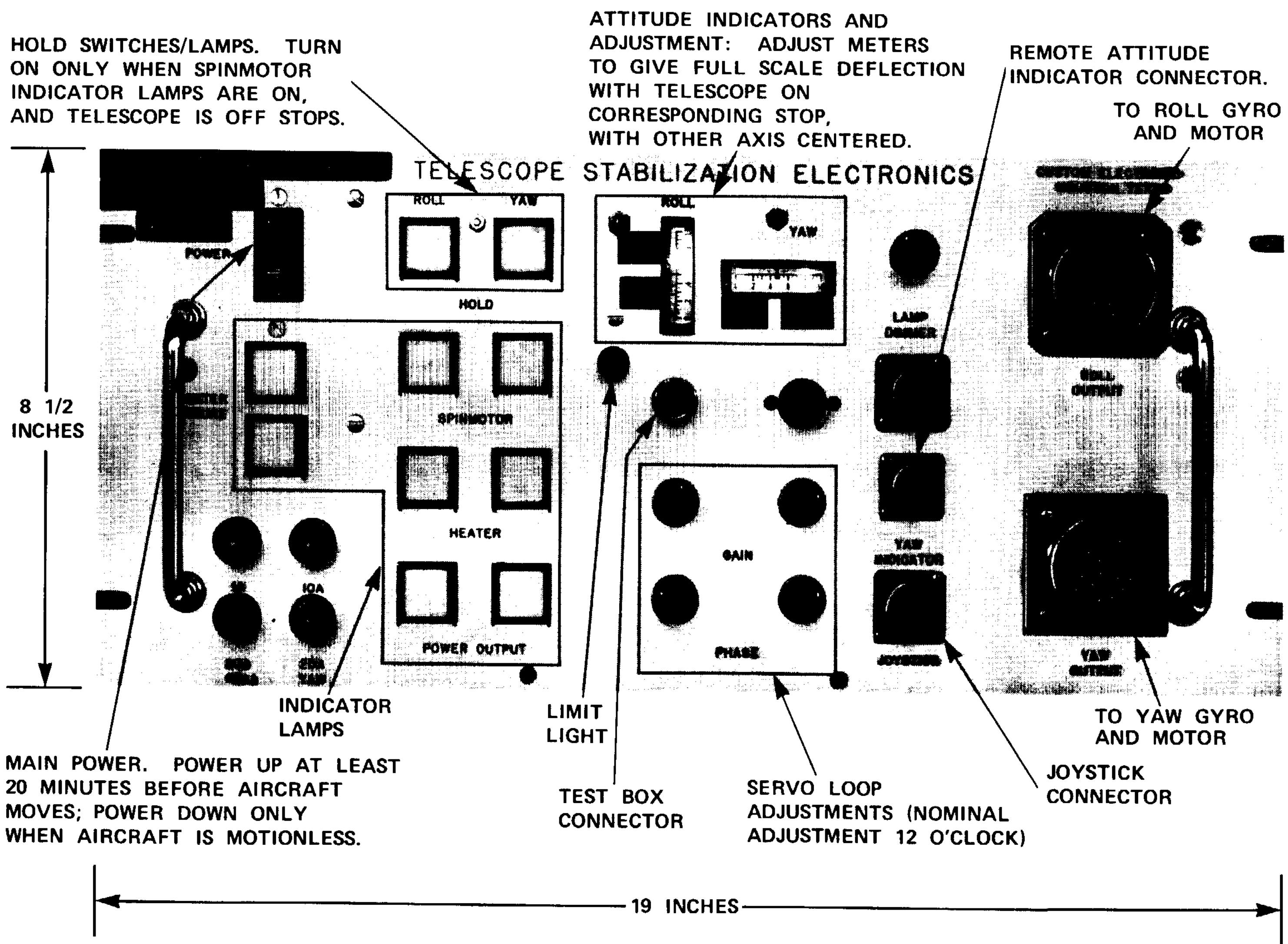

Figure II-6 Telescope Stabilization Electronics

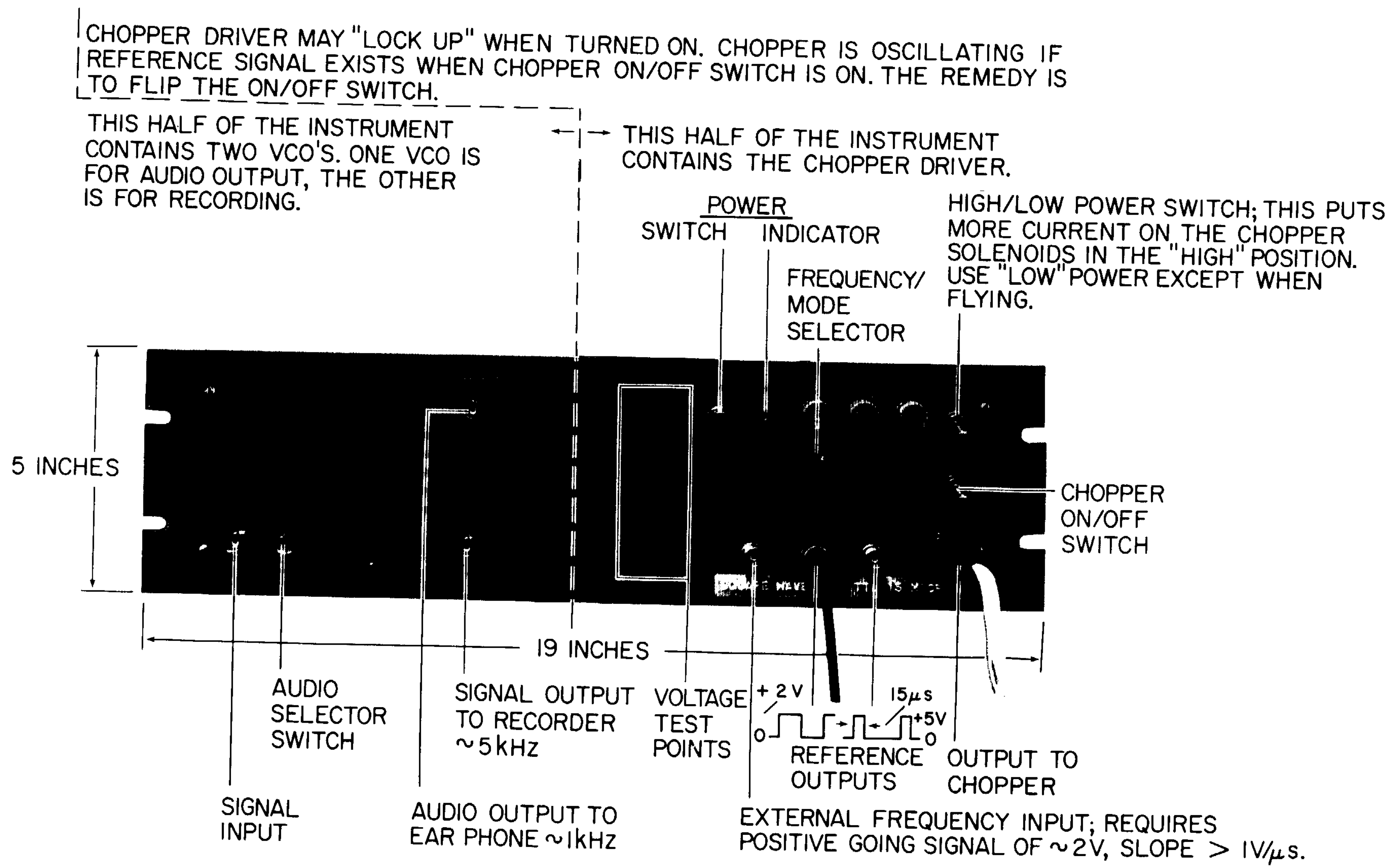

Figure II-7 Telescope Secondary Mirror Control Electronics

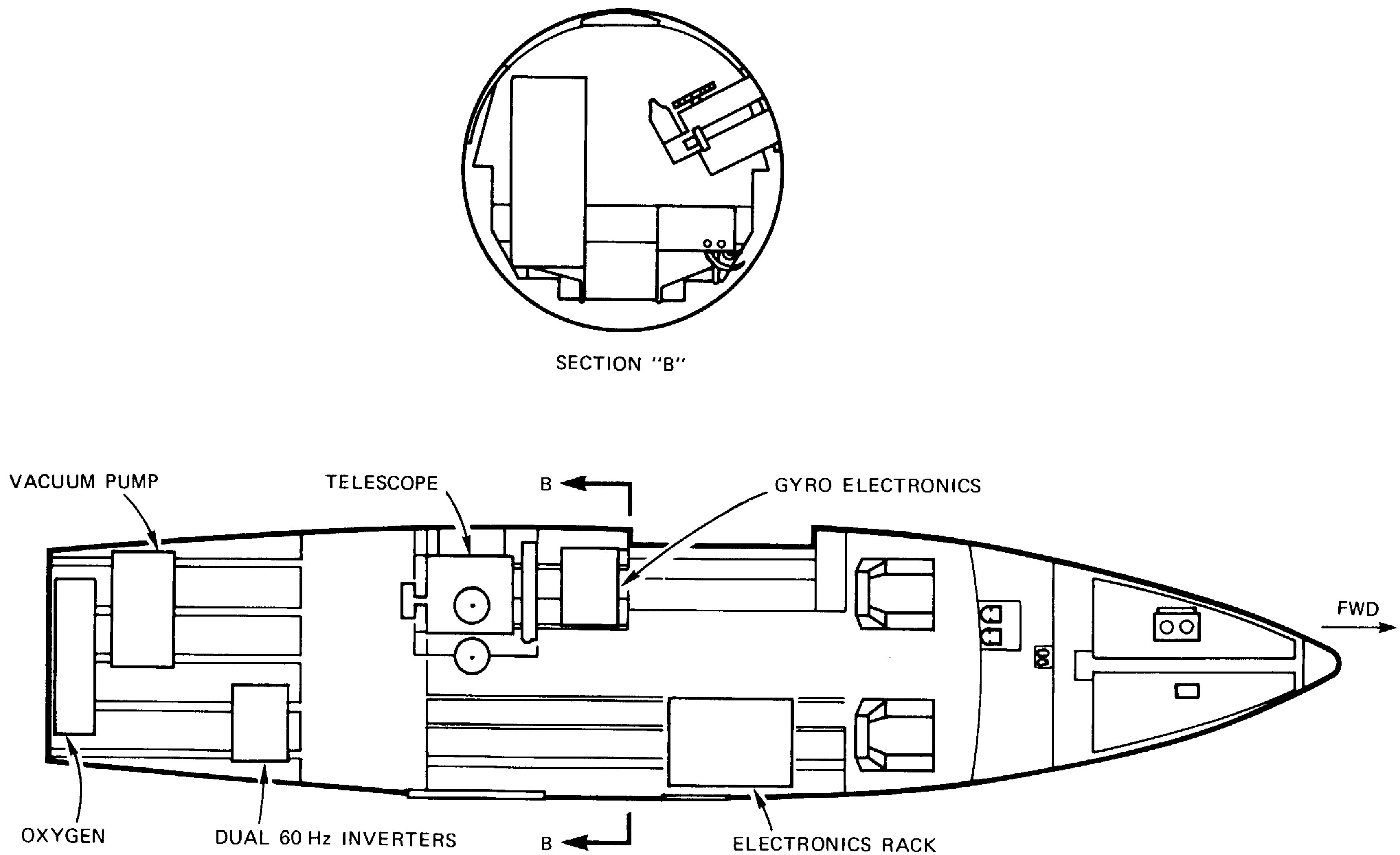

Figure II-8 Plan View of a Typical IR Astronomy Installation

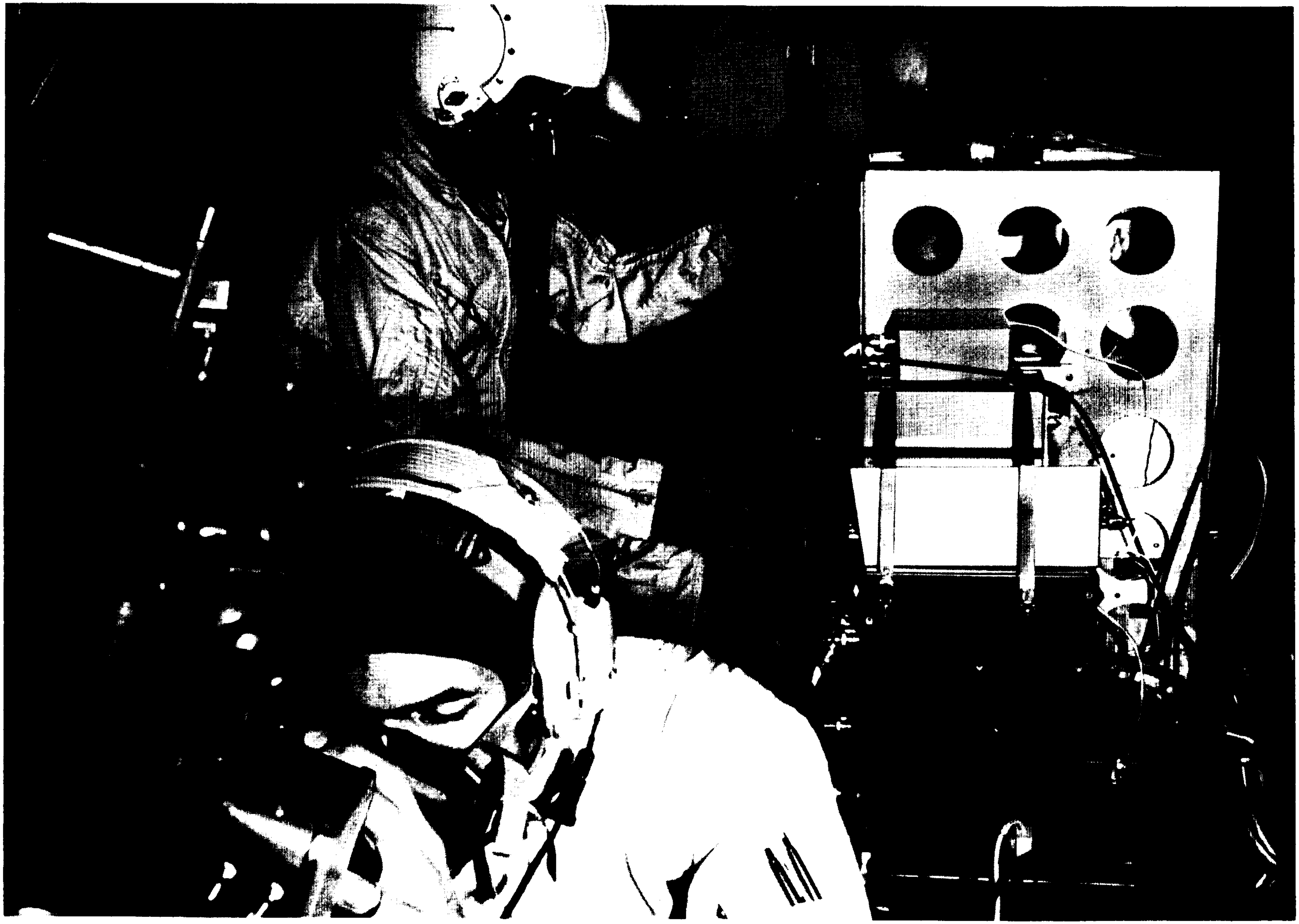

Figure II-9 Typical Observing Stations — IR Astronomy

1.2 GYRO-CONTROLLED IMAGE STABILIZERS

The Ames Research Center has three two-axis line-of-sight image stabilizers that may be used by Investigators (Figures II-10 and II-11). These instruments consist basically of a two-axis gimbal with a cast aluminum Kanogen-coated mirror rigidly attached to the inner axis and the associated electronics.

The oval mirror, 33.0 X 57.2 cm, is optically flat to 0.6 wave/cm. The unit may be mounted on a variety of instrument platforms and is designed to reflect the line of sight from athwartship in either a fore or aft direction longitudinally along the aircraft. It is the Investigator's responsibility to design his instrument platform to accommodate the image stabilizer.

The mirror is rotated by DC torque motors which are controlled by two gyroscopes sensing aircraft motions. One gyroscope senses motion about the roll axis (outer gimbal), and the second gyroscope detects components of motion about both the pitch and the yaw axis (inner gimbal). The uncorrected components of yaw and pitch result in a rotation of the image about the line of sight which is usually $\pm$ 0.25° or less. The linear stability of the line of sight is better than $\pm$ 10 arc seconds rms for periods of a few seconds. These values have been found to hold even in light turbulance. To compensate for the double-angle reflection of the mirror, the inner gimbal is driven at half the speed of the outer gimbal.

The mirror may be electrically slewed 360° about the outer axis and $\pm$ 20° about the inner axis through the use of a small control paddle. This paddle contains a two-axis control stick which provides slew rates proportional to stick displacements. When in the uncaged mode, the operator may override the gyros to compensate for slow random drifts. The paddle also contains adjustments to trim for minimum inertial drift.

Each gyro-controlled image stabilizer requires 4.2 amp (peak) of 400 Hz, 115 V power. The necessary cables and connectors are provided by the Ames Research Center. The gimballed mirror weighs 37 kg and the associated electronics console weighs 29 kg.

One installation of the gyrostabilized mirror system using the forward right passenger window on the Learjet is shown in Figure II-11. With minor modification the unit can also be installed on the port side of the cabin. However, it must not restrict the use of the door or the emergency hatch.

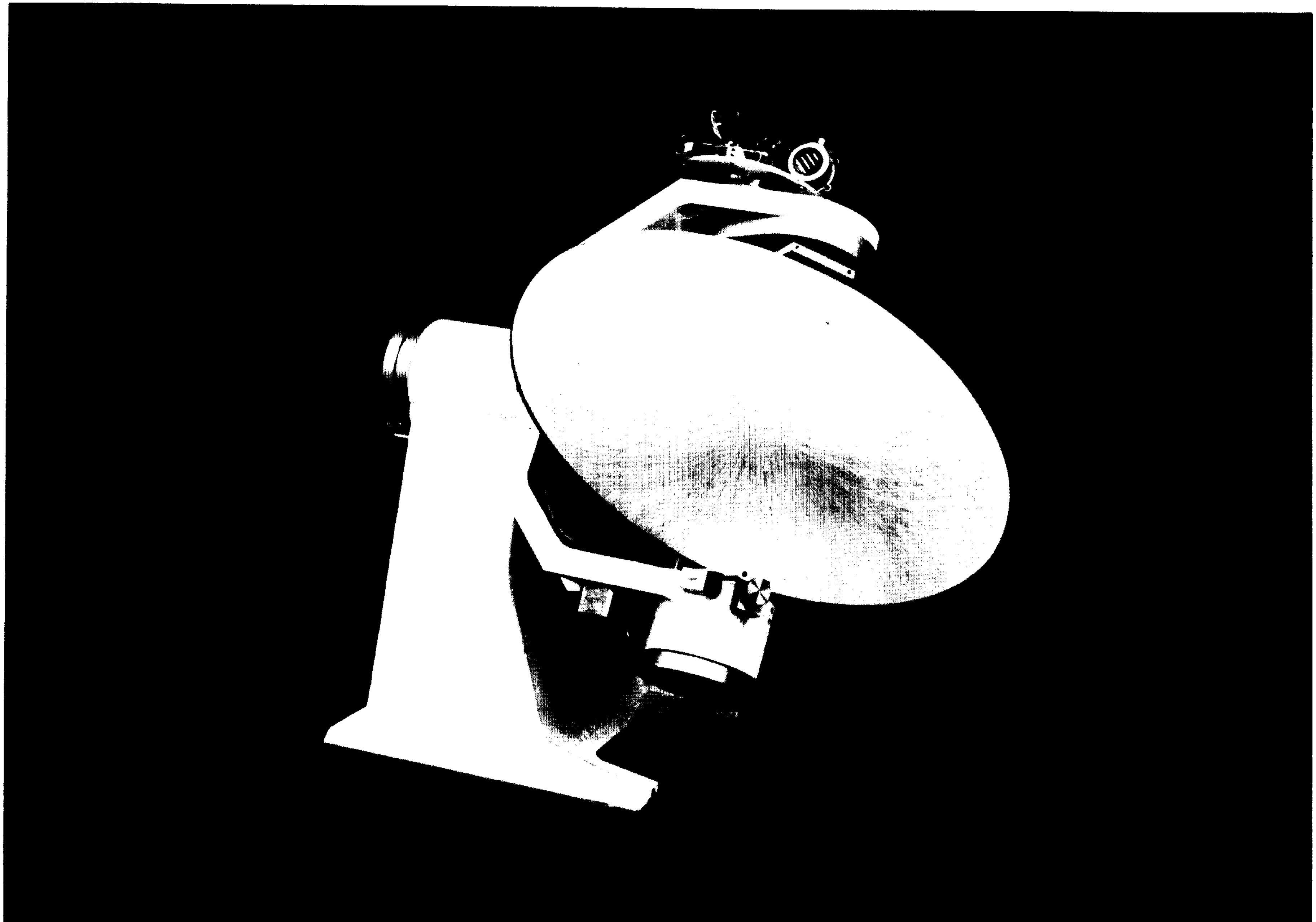

Figure II-10 General View of Gyrostabilized Mirror

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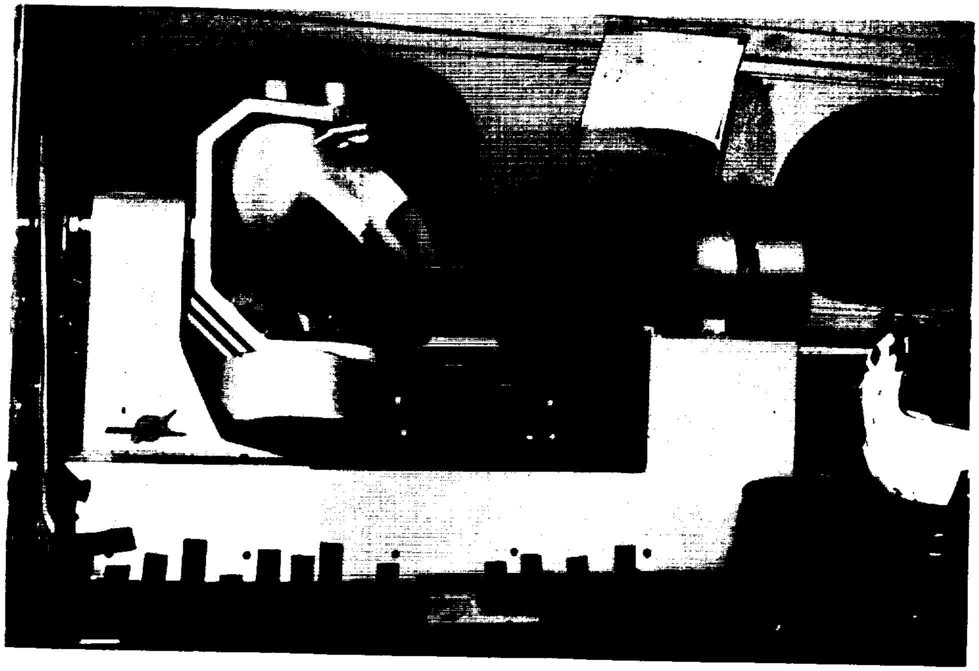
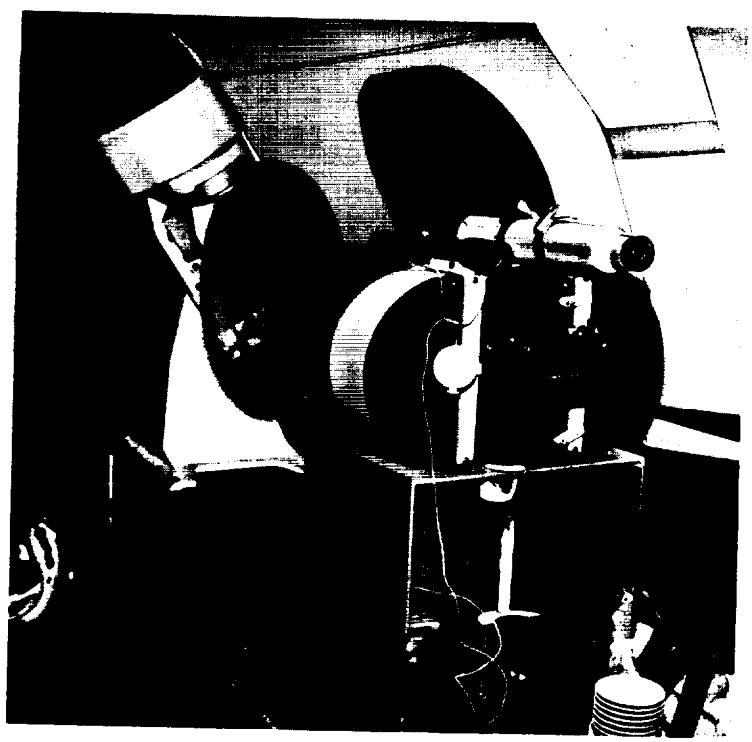


a) View Through Main Hatch



b) View Looking Forward

Figure II-11 Installation of Gyrostabilized Mirror and Camera in Learjet Cabin

NASA LEARJET AIRBORNE OBSERVATORY

INVESTIGATOR'S HANDBOOK

S E C T I O N   III

INVESTIGATOR EQUIPMENT DEVELOPMENT

1.0 COORDINATION AND PLANNING

In general, an Investigator's initial contact with the Learjet Airborne Observatory will be with the Airborne Astronomy Program Manager who is responsible for overall scientific liaison with the Investigator and with the NASA Headquarters Program Office. He is also responsible for the overall management and operation of the observatory.

The Facility Manager is responsible for mission management, detailed planning, scheduling, and daily operation of the observatory. In addition, a number of Airborne Science Office personnel and contractor individuals are available for consultation and technical assistance if needed. The Facility Manager will arrange for this assistance and will provide a nominal amount of technical help in the form of installation manpower and use of certain established NASA/Ames shops and laboratories.

The names of persons closely associated with the Learjet Airborne Observatory are listed below. Investigators are encouraged to maintain close association with these individuals throughout the development and operation of their airborne research program:

AIRBORNE ASTRONOMY PROGRAM MANAGER

Robert M. Cameron
M. S. 211-12, Ext. 5338

FACILITY MANAGER

Robert H. Mason
M. S. 211-12, Ext. 5348

FLIGHT PLANNING AND NAVIGATION

John W. Kroupa
Robert B. Morrison
M. S. 211-12, Ext. 5345

MAILING ADDRESS:

Airborne Science Office
M. S. 211-12
NASA/Ames Research Center
Moffett Field, California 94035

TELEPHONE:

(415) 965-XXXX
(Direct dial extension)

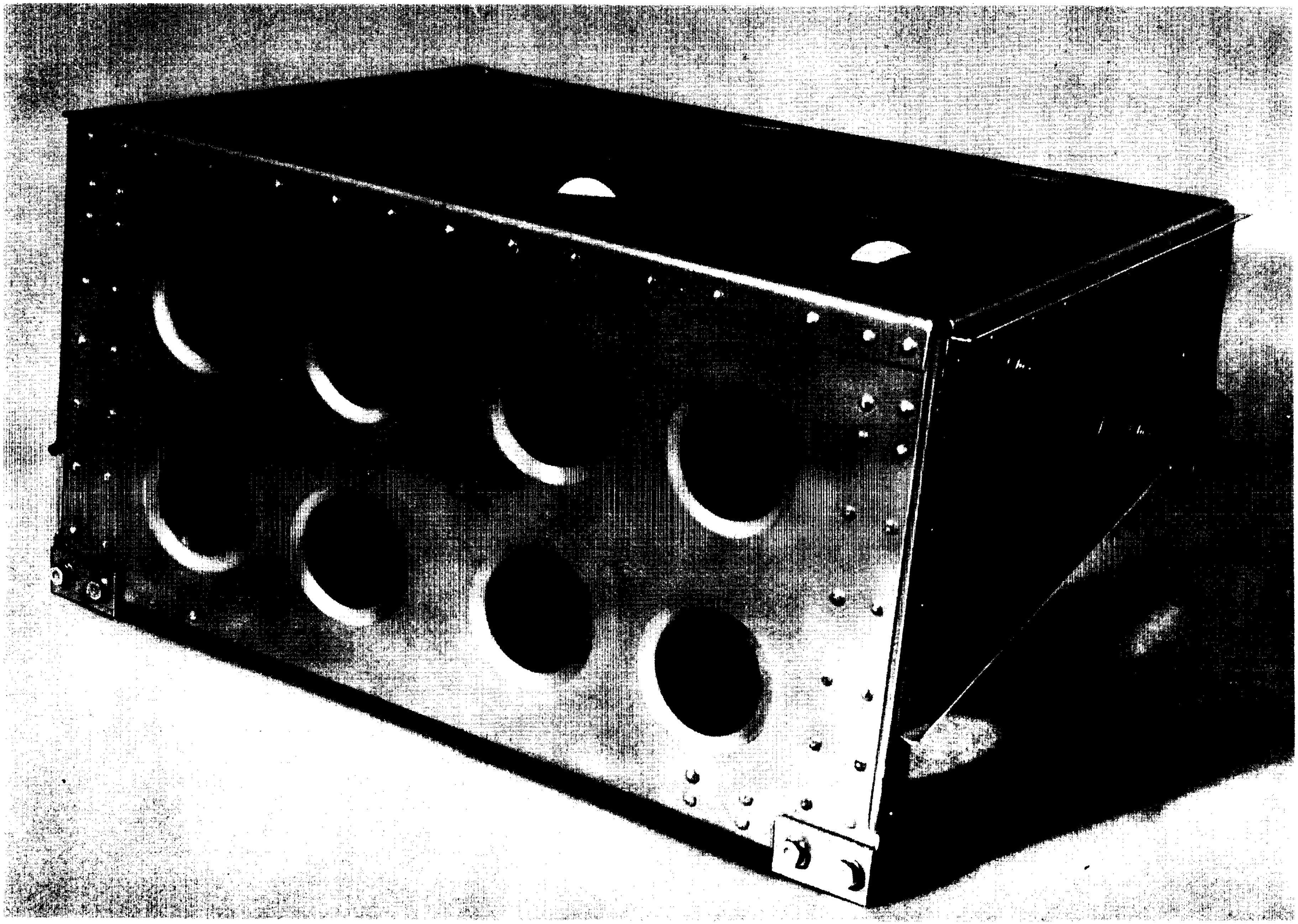


Figure III-1 Low Platform Equipment Rack

2.0 EQUIPMENT CONSTRUCTION AND INSTALLATION

The installation of investigator equipment aboard the Learjet is time-consuming and demanding. Investigators often do not fully appreciate the problems encountered in the proper installation and securing of airborne equipment so as to meet standard safety and airworthiness requirements. The following paragraphs will describe or reference standards and specifications which the Investigator *must* meet in order for his equipment to qualify for airborne research in the Learjet.

The standards presented fully meet or exceed all FAA and Ames Research Center requirements for the Learjet type and category aircraft.

2.1 AIRWORTHINESS AND SAFETY CONSIDERATIONS

It is possible that certain areas of design normally acceptable for ground-operated equipment can cause hazardous conditions aboard a jet aircraft flying to high altitude. The following items are covered briefly as reminders of the necessity to maintain a high level of safety aboard the Learjet. Further, these concepts of design and construction will do much to enhance the operational reliability of Investigator equipment.

2.1.1 Material Stability

Several factors should be considered by the designer before selecting materials for a specific function. They must not be capable of supporting combustion, and should of course be stable at expected operating temperatures. Tests have shown that certain insulating and impregnating materials used in the manufacture of inductive components such as transformers, coils, chokes, etc., can liberate explosive gases when the component is operated at elevated temperatures. Further, some materials outgas at the low ambient pressures typical of the Learjet cabin during high altitude operations. The Investigator should be cautious in the selection or design of only those components or materials which will not be functionally or physically degraded by cabin environments.

2.1.2 Electrical Considerations

Steps should be taken to prevent corona, electrical arcing or damage at reduced atmospheric pressure. If necessary, hermetic sealing and pressurization may be employed. Additionally, the following objectives should be considered in design and layout of cables:

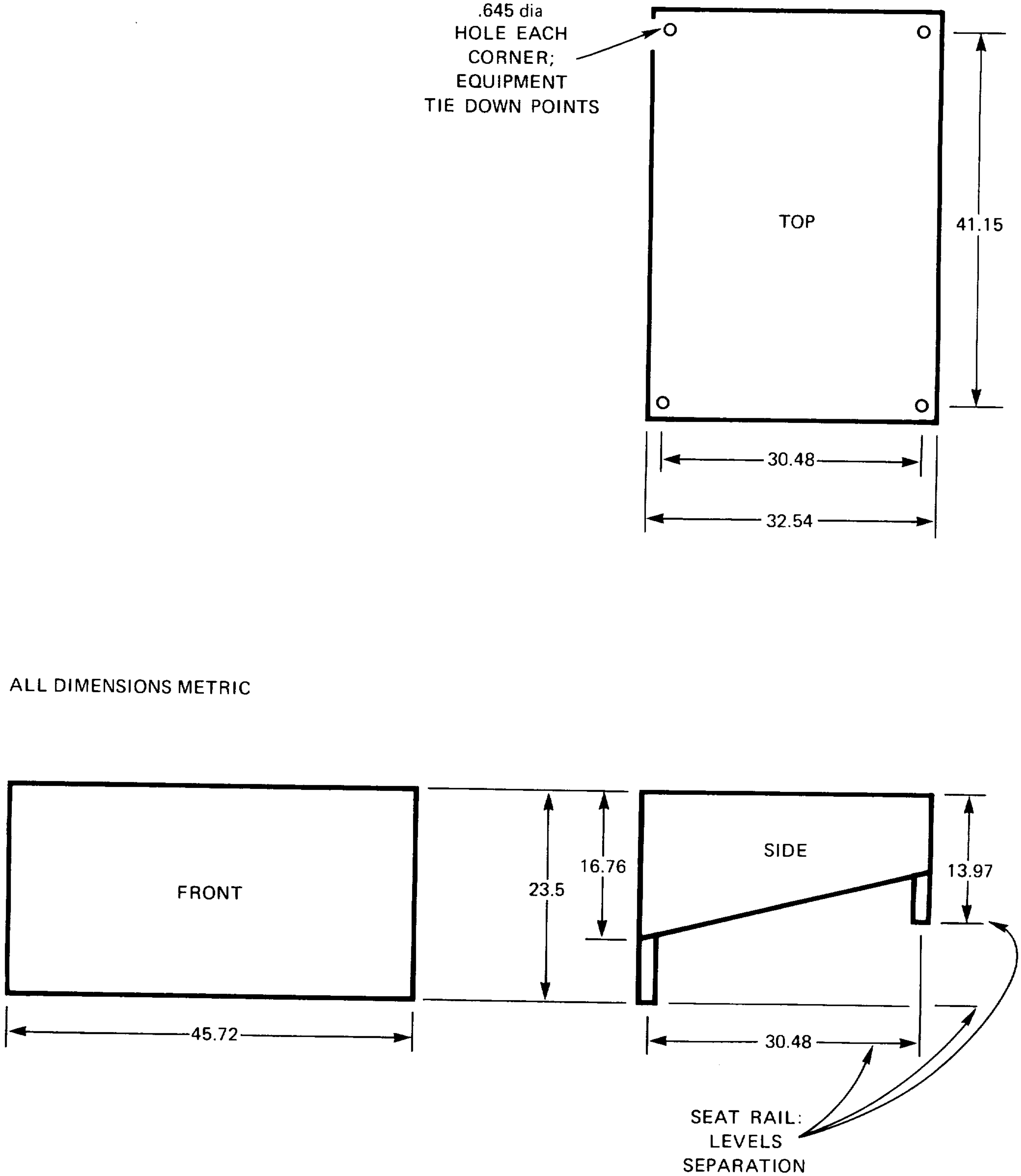


Figure III-2 Plans of Low Platform Equipment Rack

a. prevent physical interference with other systems

b. prevent coupling interference between systems or equipment

c. provide access for maintenance and troubleshooting

d. minimize possibility of damage during normal and abnormal use

e. provide abrasion resistance

f. provide design for maximum reliability

g. provide for sufficient stress relief of cables and connectors

Signal and power leads should be physically separated to prevent coupling, and signal leads should be shielded where practical. Wire types and sizes shall be selected for compatibility with anticipated voltages and currents. Well-controlled soldering and workmanship procedures and practices will contribute significantly to the reduction of equipment failures.

2.1.3 Human Engineering

Investigator equipment *must* be designed for non-hazardous normal and emergency operation. Connectors should be clearly identified. All indicators used for monitoring adjustments should be placed so that they are readily observed during the adjustments. Fuses and circuit breakers should be readily accessable without removing other components. All terminals having potentials exceeding 50 volts shall be insulated to prevent accidental human contact.

2.2 LOAD FACTORS - SAFETY STANDARDS

All equipment, including racks, instruments, pallets, and tie-down bracketry must be designed for the load conditions listed in Table III-1. These load factors, when applied one at a time, must not produce a stress in any element of the equipment beyond the accepted ultimate strength point for the construction material. The load factors as presented are fully applicable to all equipment installed aboard the Learjet Airborne Observatory.

The requirements are for structural design of the equipment. It is not required that alignment, calibration, or other strictly instrumental functions be maintained under these load conditions.

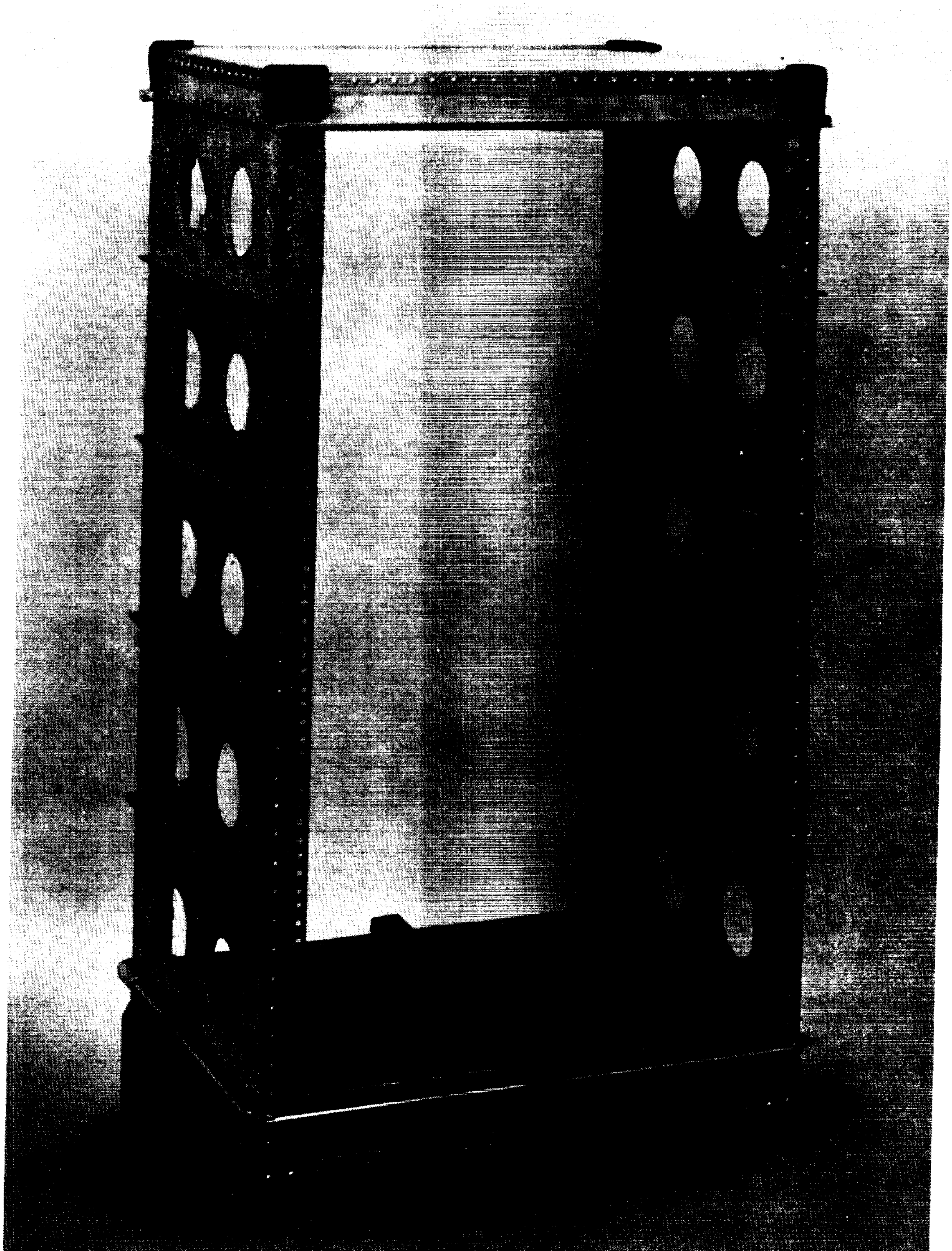


Figure III-3 Standard Equipment Rack – Rear View

TABLE III - 1

LOAD CONDITIONS

Load Direction	Load Factor
Forward	9.0 g
Down	7.0 g
Up	2.0 g
Side	1.5 g
Aft	1.5 g

2.3 AIRCRAFT FASTENERS AND WELDING

MS or NAS standard aircraft structural fasteners approved by the Ames Research Center are to be used for all structural members and must be secured by self-locking nuts or safety wire. In addition to mandatory use for structural members, this type of hardware should also be used for other elements of the equipment whenever possible. The Airborne Science Office will provide these fasteners. Contact the Learjet Facility Manager.

Welding of structural members of experimental equipment is acceptable. However, it *must* be high quality work performed by a welder *currently* certified to specification MIL-T-5021C.

2.4 EQUIPMENT RACKS

Two types of standard equipment racks are available, one low platform, and one designed to accept standard 48.3 cm wide, rack-mounted electronic equipment. Both attach directly to the seat rails.

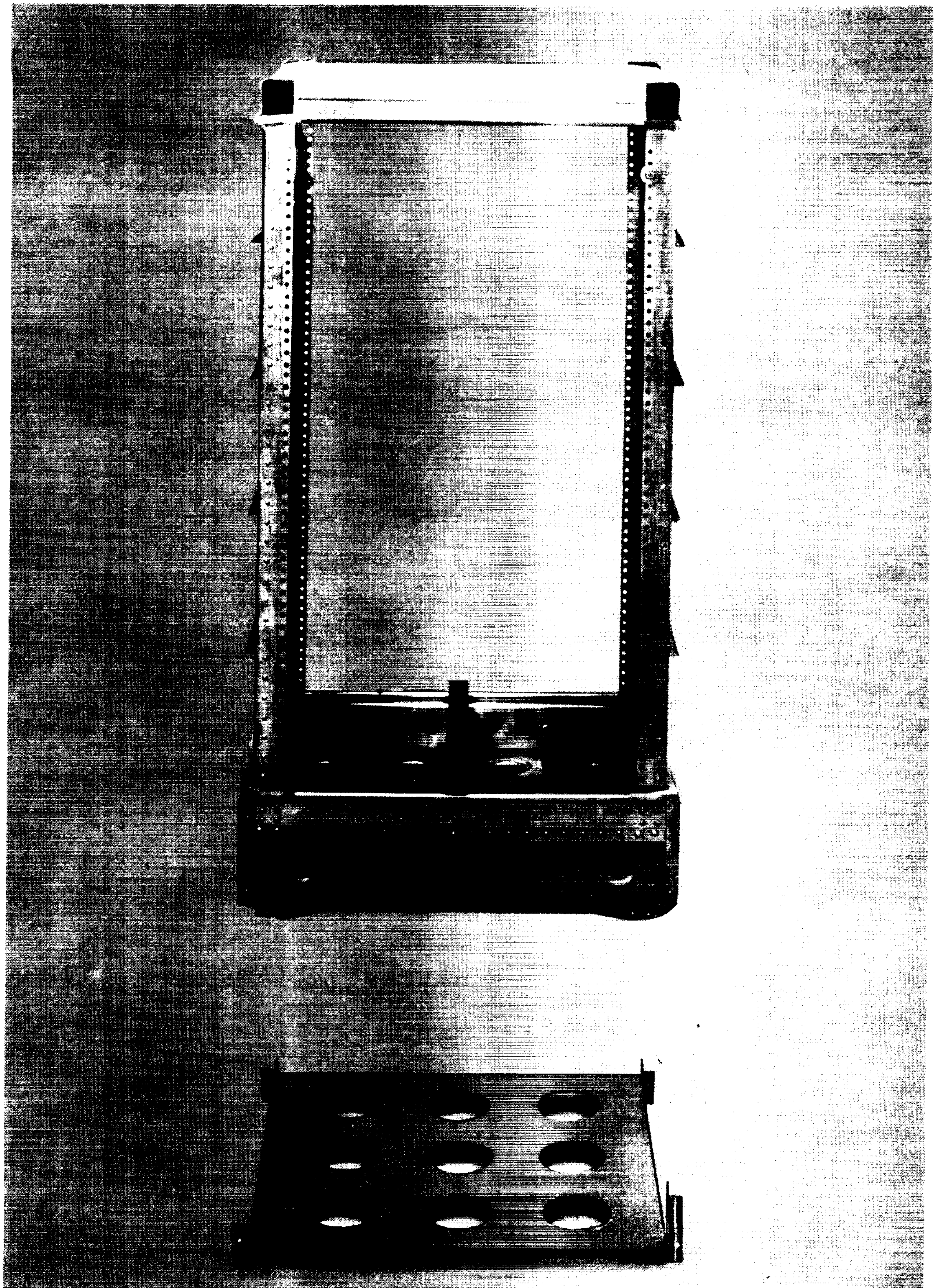


Figure III-4 Standard Equipment Rack, Front View

The low platform is shown in Figures III-1 and III-2. Equipment is mounted only on top of this rack and tie down points are located at each top corner.

The rack for electronic equipment is shown in Figures III-3 and III-4. This rack also has tie points for mounting equipment on its top. However, vertical clearance above the installed rack is only 20 cm inboard and 3.8 cm outboard, so this space is of limited usefulness.

The allowable weight of equipment that can be mounted in or on these racks is 85.3 kg, and the maximum overturning moment is 37.7 kg-m. Moment arms are measured vertically from the top of the inboard or lower seat rail to the center of gravity of the component considered. These maximum values take into account the load conditions given in Table III-1. For installations which do not exceed allowable values, a stress analysis of the rack is not required. A rule of thumb for loading the rack is to place the heaviest items as near the bottom as possible. Refer to Section VI, Reference A.

Individual components mounted in the electronics rack will probably need support other than that provided by the front face mounting panel. There are no simple rules for making this determination. The primary factor, however, is the weight of the component as related to the height of the front mounting panel. This distribution of component mass also enters into consideration. In general, the decision concerning extra support is made by the Facility Manager at the time of installation. No matter what the panel height, a support tray as shown in Figure III-4 is used under every component weighing 22.7 kg or more to facilitate ease of handling.

Approved mounting hardware, scale drawings of the equipment racks, and even a complete rack will be shipped to the Investigator upon request to the Facility Manager. When a complete rack is shipped, a nominal supply of support trays, straps and hardware will also be included. *Under no circumstances is a rack to be physically altered (e.g., holes, cuts, etc.) by the Investigator without written permission from the Learjet Facility Manager.*

In preparing for installation of equipment in a rack, it is recommended that the Investigator make a preliminary scale layout taking into account the allowable loads and moments. Cognizant personnel from Ames will determine additional support and bracing required to distribute the load properly over the rack structure. To do this, it will be necessary to know the weight and approximate center of gravity of each rack-mounted component. A typical installation of equipment in the Learjet is shown in Figure III-6.

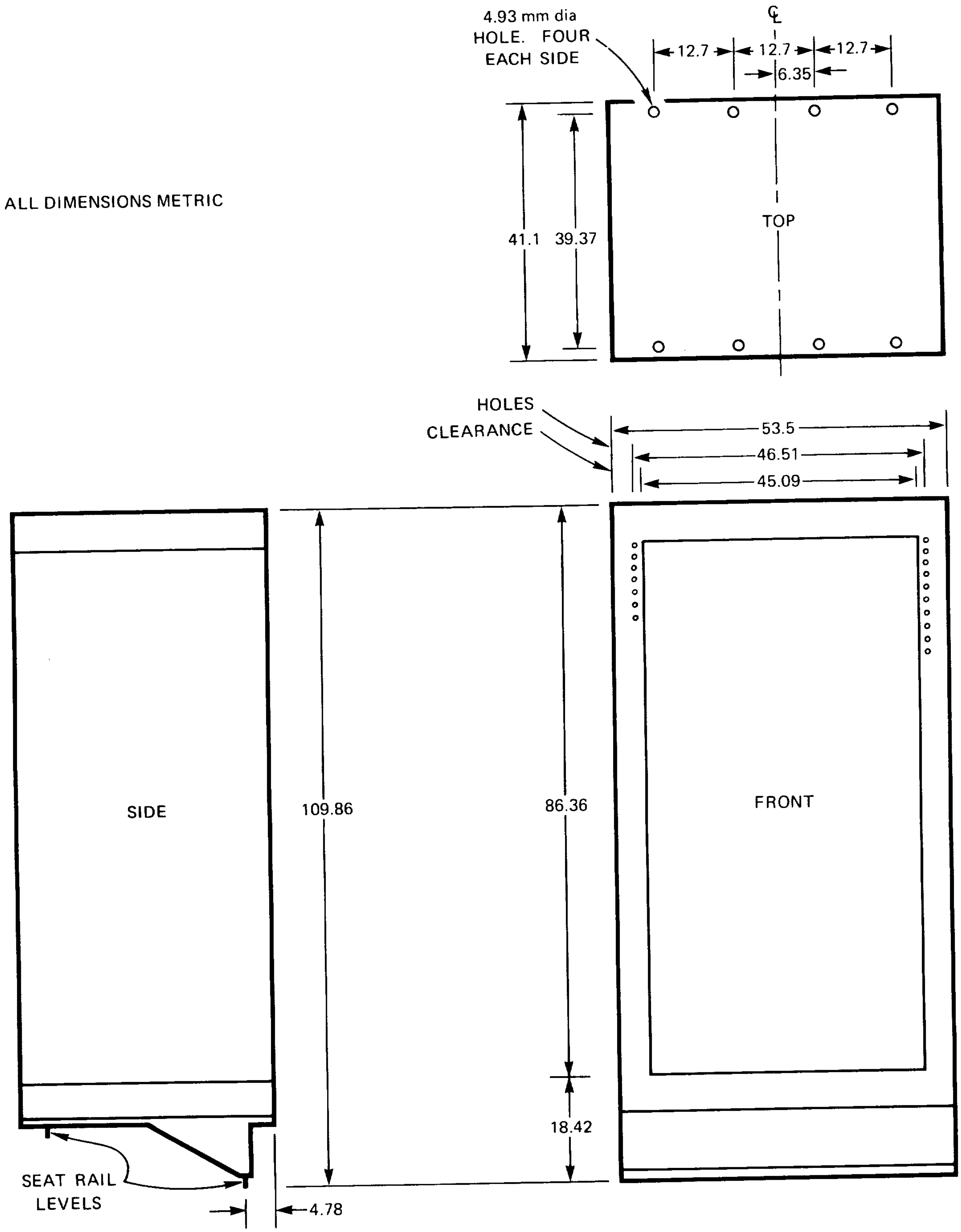


Figure III-5 Plans of Standard Equipment Rack

2.5 MOUNTING TECHNIQUES

All items, regardless of size, must be secured during takeoff and landing. While airborne, it is permissible to relocate items which are soft, or which can be made soft by padding, and which weigh less than 4.5 kg. Because of the possibility of gust loads, these items must again be secured after relocation. Personal briefcases, cameras, binoculars, etc., are *definitely* included in this requirement.

2.6 CABIN AREA

All equipment must be supported by the seat or baggage compartment tracks by using one or more of the racks described above or by special mounts required by the experiment. Direct bolting to the aircraft floor or cabin wall is *not allowed*. The maximum allowable load factor that can be applied to each track attachment fitting is listed in Table III-2. For large racks of equipment, the load can be distributed over several track attachments as long as the attachments are spaced three centimeters or more apart.

Typical Investigator equipment weighs 181 to 272 kg and is fastened to the rails by several attachments. There will seldom be any concern about overloaded rails if weight constraints are not exceeded.

TABLE III - 2

MAXIMUM TRACK ATTACHMENT LOADS

Load Direction	Ultimate Load
Vertical	7.0 g
Longitudinal	9.0 g
Lateral	1.5 g

Figure III-6 IR Astronomy Installation Showing Equipment Mounted in Racks

2.7 BAGGAGE COMPARTMENT

Access to the baggage compartment is possible with the back rest of the aft passenger bench folded forward or removed. There are five equally spaced mounting rails in the compartment which can be used for attachment of experimental apparatus. It is common practice to place the inverters required for ac power, vacuum pumps, and items which do not require routine in-flight servicing in the baggage compartment. There is generally space for other apparatus as well. Usual practice is to bolt the apparatus to a 0.64 cm aluminum plate and to then fasten the plate to the rails with standard attachment hardware.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

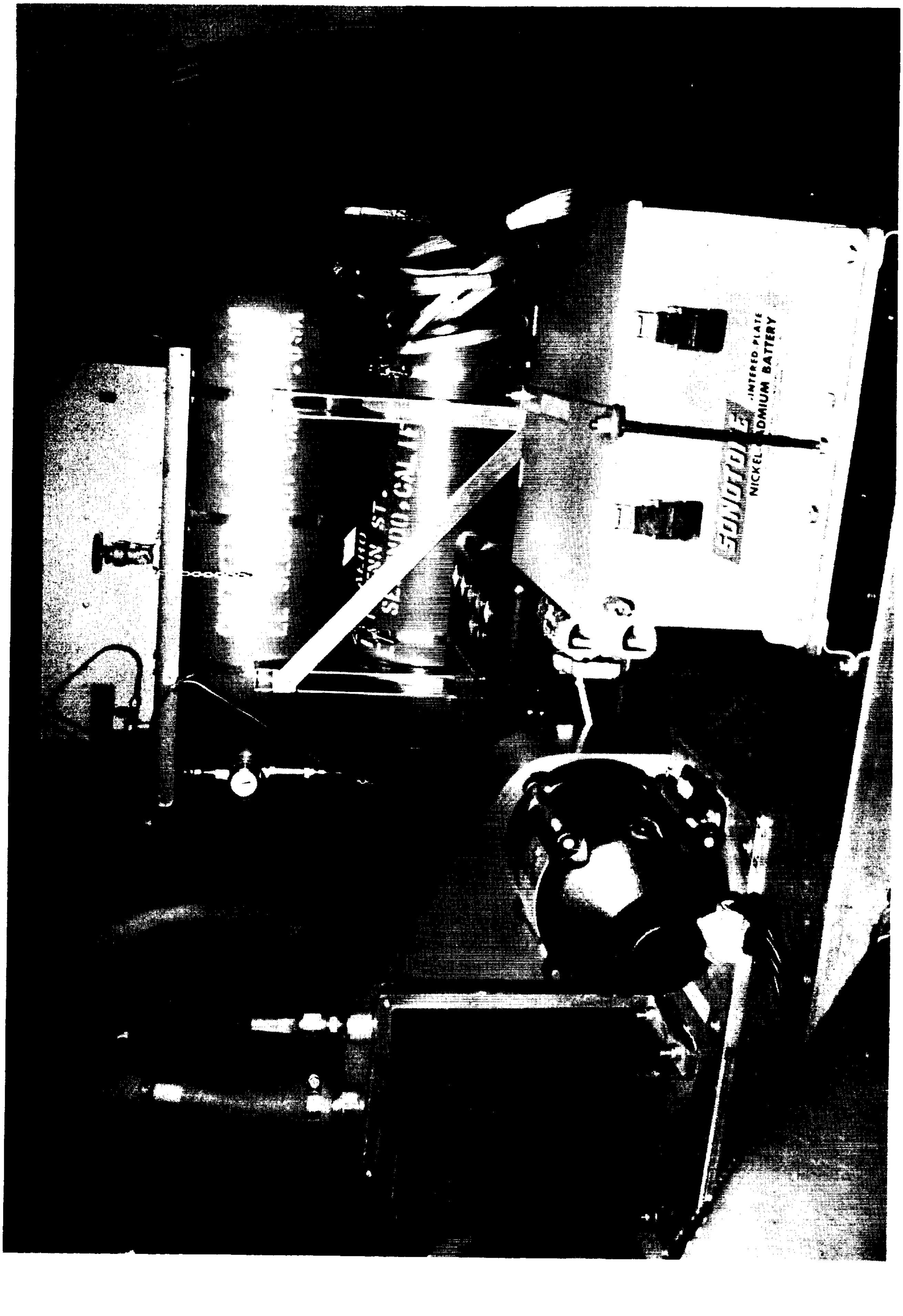


Figure III-7 Baggage Compartment (Typical Investigator Equipment Installation)

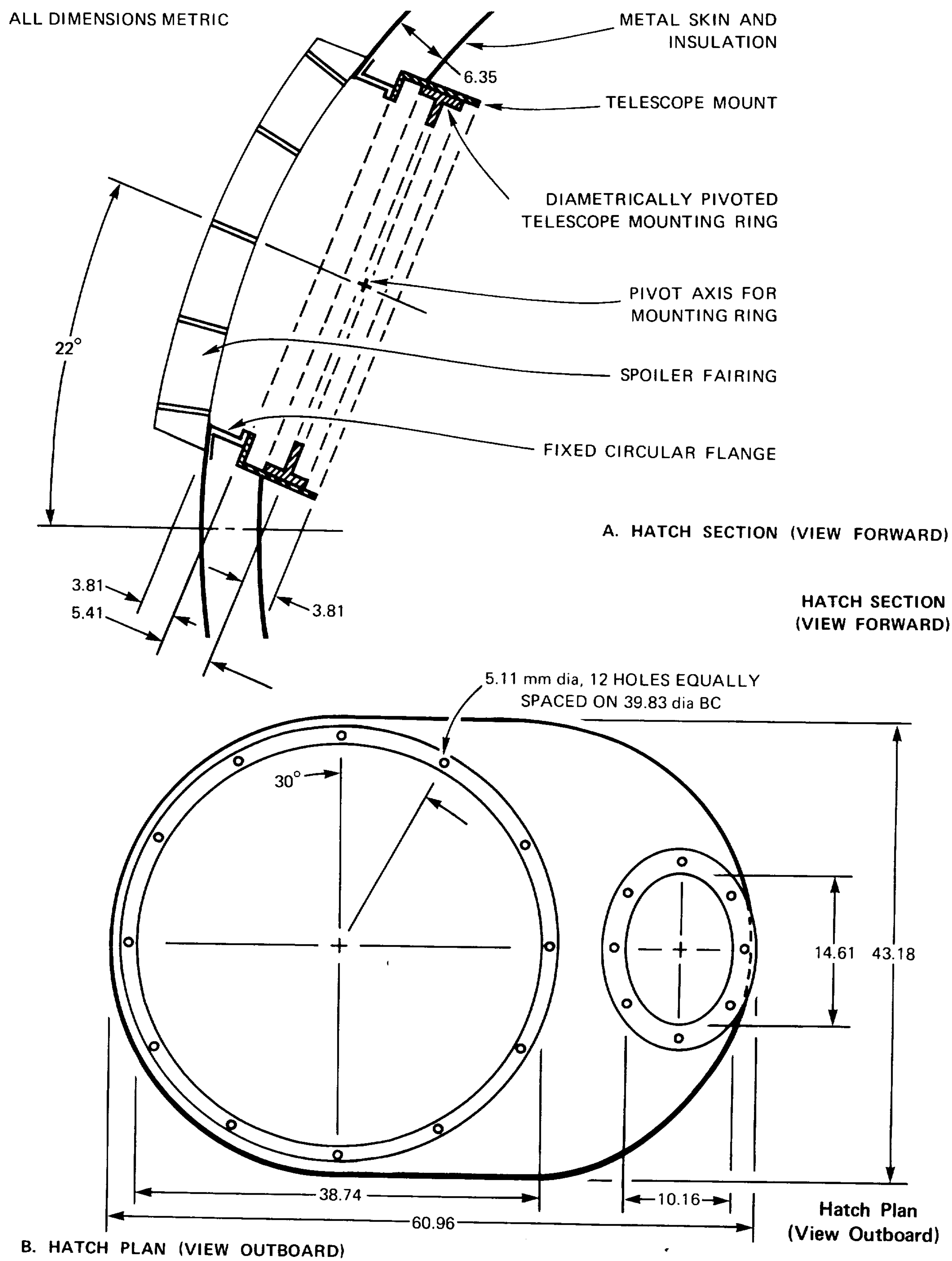


Figure III-8 Open-port Hatch Dimensions

3.0 OPEN-PORT EXPERIMENTS

The cabin window opposite the escape hatch has been replaced by a metal hatch designed for mounting open-port experiments. The escape hatch, although removable, cannot be used for mounting open-port experiments.

The open-port experiments most frequently flown, employ the 30 cm IR telescope, so the openings cut in the metal hatch are configured to the needs of this instrument. Other open-port experiments may be adapted to the existing opening. However, the hatch is a semi-permanent installation. Other open-port experiments which necessitate replacement or extensive modification to the existing hatch require strong justification.

3.1 HATCH DIMENSIONS

Pertinent dimensions and mounting hole patterns of the open-port hatch are given in Figure III-8. Note in the figure that there is restricted clearance of about 2.54 cm behind the fixed circular bolt hole flange. This is due to the thickness of the thermal insulation surrounding the hatch, and cannot be altered.

The device through which the 30 cm IR telescope attaches to this hatch is also shown in Figure III-8. The inner mounting ring is pivoted about a longitudinal axis and can be rotated through $\pm$ 3° to allow changing the elevation of the whole telescope housing. Experiments other than the telescope can be mounted on this ring if flexibility in elevation is desired. The mounting bolt circle in the ring is identical to that of the hatch. An annular pressure seal must be used between the adjustable telescope mount and the apparatus which attaches to it.

3.1.1 Hatch Weight-Bearing Capacity

The Facility Manager must be consulted in the design of equipment to be attached to the open-port hatch. The aircraft structure surrounding this window is not designed to carry more than the weight of the hatch. Equipment bolted directly to the hatch must be supported entirely by attachment to seat tracks and the support structure shall satisfy load factor requirements.

4.0 USE OF OTHER PORTS OR HATCHES

The cutting of holes or ports in load-carrying members of the aircraft is prohibited. Moreover, the Learjet is not well suited for downward viewing experiments because control cables, hydraulic lines, and air ducts run the entire length of the cabin floor. In special cases, it may be possible to utilize for a nadir port, a three-inch diameter hole which normally contains a rotating beacon amidship on the underside of the fuselage. An access hatch to the *unpressurized* cable compartment, located on the underside of the fuselage aft of the baggage compartment (Figure III-8), may be modified to accept some experiments. The usable volume above this hatch is shown in Figure III-9. Equipment mounted in this space must be designed to be easily removed, reinstalled and aligned, since the compartment must be accessible for aircraft servicing. Use of either of these spaces will require installation of special equipment mounting brackets and special hatch construction. Thus, personal inspection of the spaces and consultation with the Airborne Science Office at an early stage is recommended should such usage be contemplated.

Approval may be obtained to substitute special hatches for the escape hatch. Such hatches and the equipment associated with them must fulfill safety requirements. Figure III-10 shows a typical substitute escape hatch which satisfies safety and airworthiness requirements.

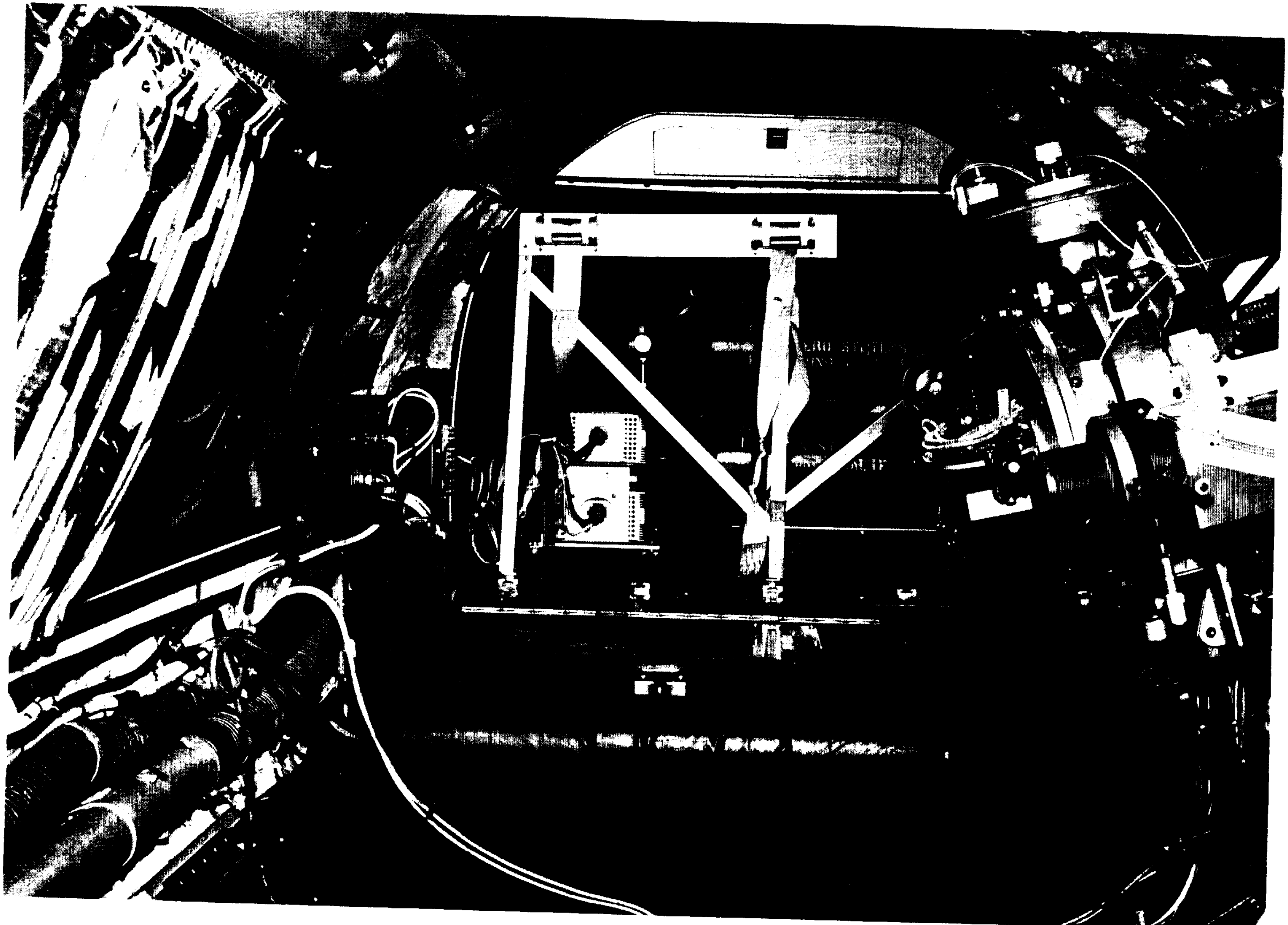


Figure III-9 Learjet Cabin – View Looking Aft

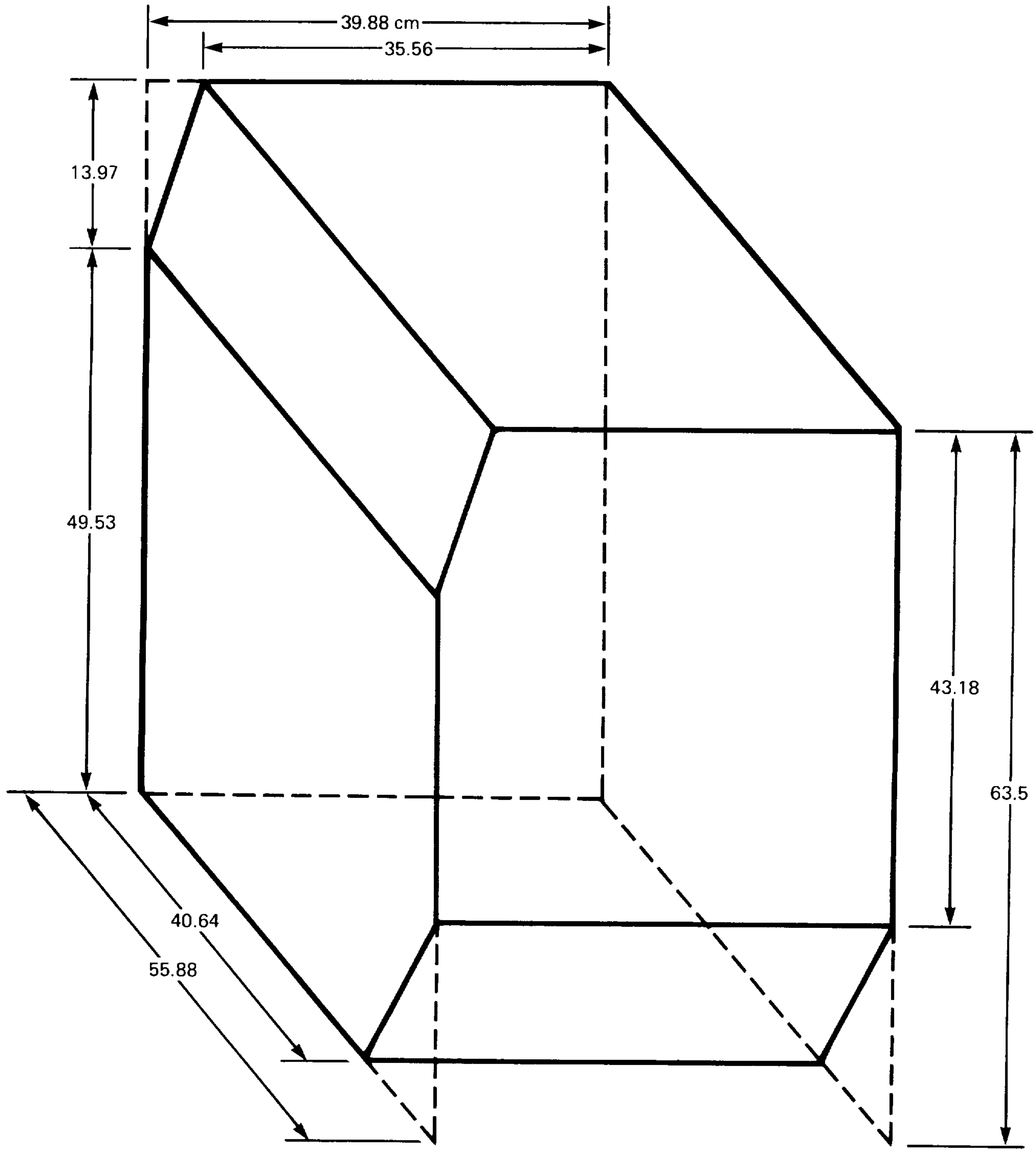
5.0 EQUIPMENT CERTIFICATION

It is the Investigator's responsibility to design and construct his equipment in accordance with the specifications set forth in this handbook. Problems may, of course, be discussed with Ames personnel at any time.

Investigators are required to submit *detailed drawings* of their equipment which show dimensions, materials, bolt types and patterns and component weights. If possible, photographs of the equipment should also be furnished. *Stress calculations must accompany the drawings.* These calculations must include, as a minimum, the following: load analysis of seat tracks, analysis of support and tie-down structure, and analysis of restraining structure for components (e.g., racks within a cabinet).

All of the required information should be submitted at least *eight weeks* prior to scheduled installation of the equipment aboard the aircraft. The Investigator's design data will be analyzed by Ames personnel, or by a contractor under Ames supervision, and changes will be requested as needed to meet safety requirements. Preliminary approval should be obtained from the Learjet Facility Manager prior to shipment of equipment to the Ames Research Center.

Actual equipment construction, weight, center of mass, and resultant loading are verified at the Ames Research Center before final approval for installation aboard the aircraft is given. Allow time for this verification (approximately one day) when planning installation time.



ALL DIMENSIONS METRIC

Figure III-10 Dimensions of Usable Unpressurized Space

6.0 PORTS AND WINDOWS

6.1 PASSENGER WINDOWS

With standard emergency exit installed, there are three cabin windows; two on the starboard side and one on the port side (see Figure I-5). Each of these windows is a 43.2 X 61.0 cm Plexiglas oval of 1.27 cm thickness. The optical transmission of this window is presented in Figure III-11.

6.2 OPTICAL WINDOWS

Optical windows may be mounted in a special hatch designed for this purpose as shown in Figure III-13. To fit the hatch, dimensions must be 38.1 X 33.0 cm with corners rounded to radius 9.0 cm and not more than 3.2 cm thick. Windows smaller than the aperture of the hatch may be installed by fabricating special adapters which have the outside dimensions given above.

It is imperative that the glass be isolated from metal adapters and retaining frames by silicone-rubber gaskets, and that the tolerance between the glass and adapter or frame be sufficient to prevent strain on the glass due to thermal effects or due to pinching under a pressure load. In addition, all edges of the glass should be chamfered to prevent chipping of the glass or damage to the gasket. Under no circumstance will glass with a scratch or large unsmoothed chip be installed on the aircraft.

The Ames Research Center has a number of optical quality windows that fit the hatch. The different types of windows are: fused silica (GE 105), quartz, soda lime glass, borosilicate-crown glass, and Pyrex. Optical data are maintained on these windows and are available upon request. Figure III-15 shows typical transmittance curves for quartz and Pyrex windows.

If use of one or more of these windows is anticipated, the Facility Manager should be notified as soon as possible. Some of the windows are used aboard other NASA aircraft, and thus may not be available for use aboard the Learjet. Table III-3 gives the minimum thickness as a function of window dimensions for several window materials.

Figure III-11 Unpressurized Cable Compartment

TABLE III - 3

MINIMUM THICKNESS OF WINDOW MATERIALS

MATERIAL	DIMENSIONS		
	Outside Diameter (cm)	Clear Aperture Diameter (cm)	Minimum Thickness (cm)
Soda-Lime, Borosilicate	3.81	2.54	0.25
Crown, Quartz, Fused	6.35	5.08	0.51
Silica, or Cervit	12.0	10.16	1.02
	17.15	15.24	1.52
	22.86	20.32	2.03
	27.94	25.4	2.54
	33.02	30.48	2.54
Arsenic Trisulfide,	5.08	2.54	0.51
Calcium Flouride,	7.62	5.08	0.76
Ruby, Irtran,	13.97	10.16	1.27
Polyethylene,	19.05	15.24	1.78
Polypropylene, Etc.	24.13	20.32	2.29

NOTES: a) The above are minimum thicknesses. Greater thicknesses are allowable up to the limit of available space. In general, the maximum thickness that can be accommodated is 3.18 cm.

b) For non-circular windows, the minimum thickness is governed by the largest diagonal dimension.

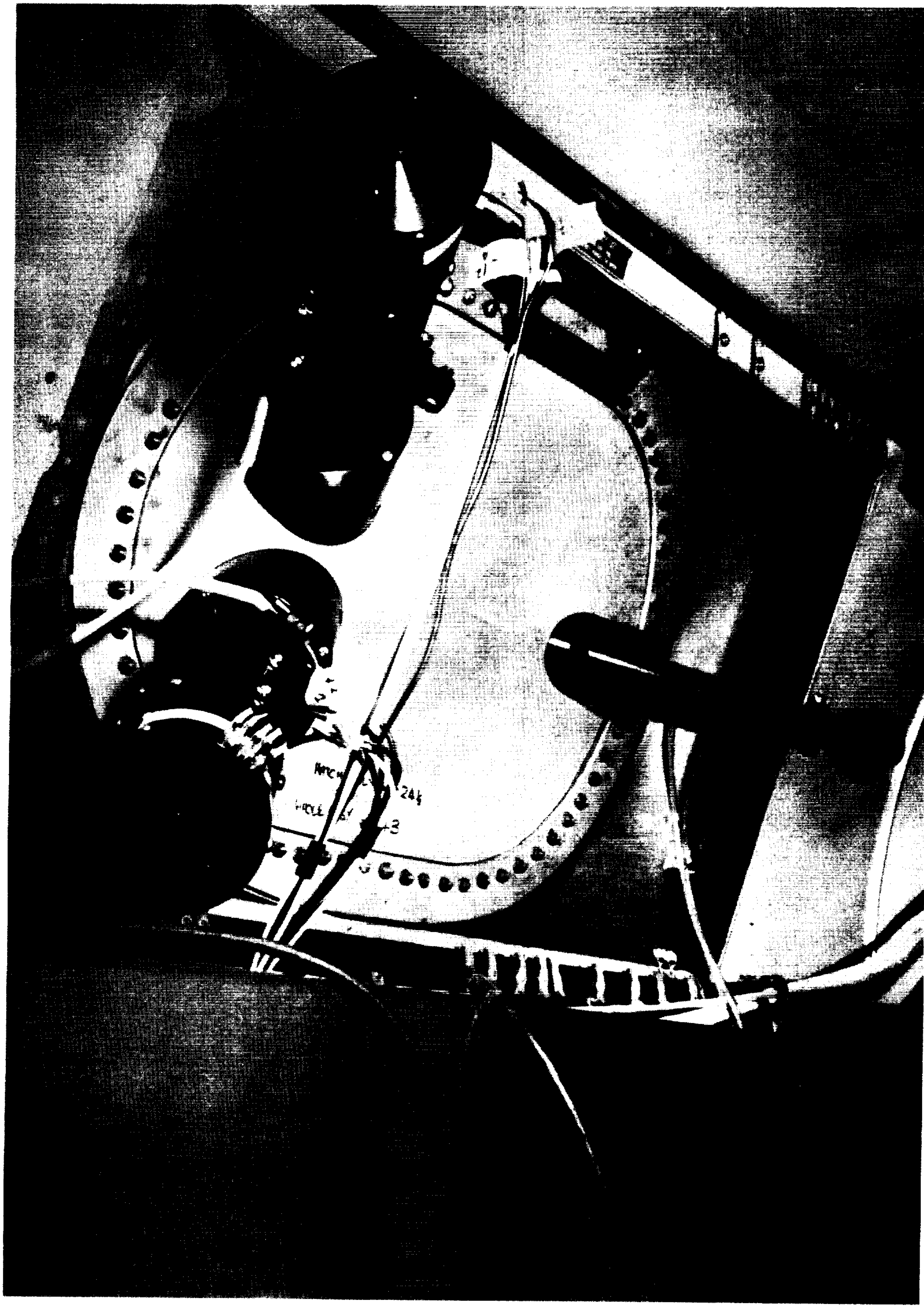
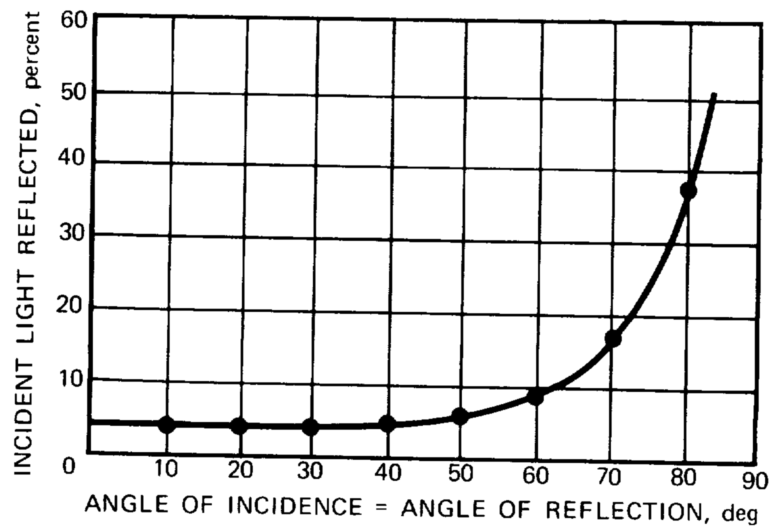
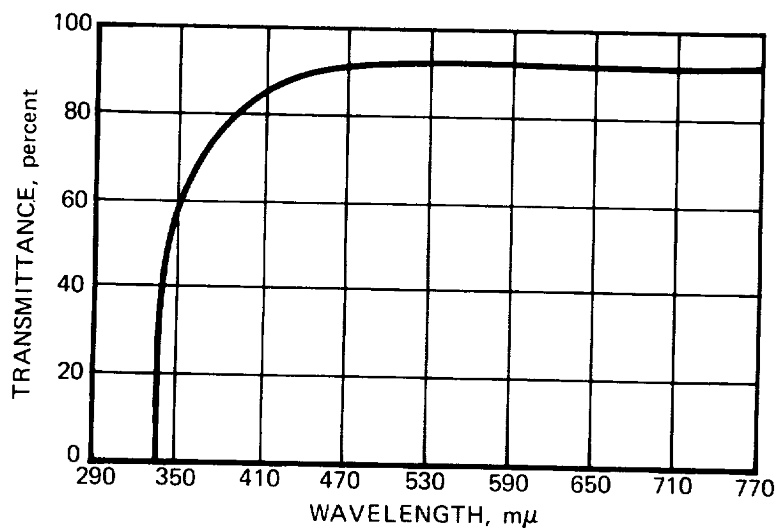


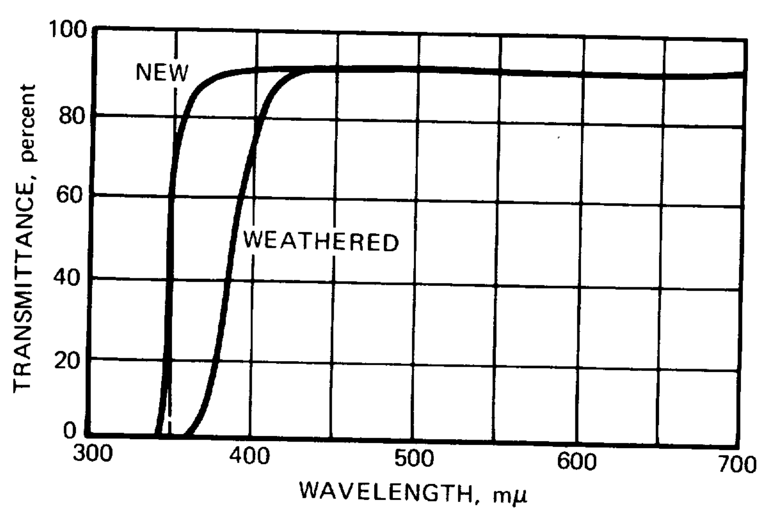
Figure III-12 Example of Escape Hatch Utilization



A. REFLECTION FROM PLEXIGLAS FOR UNPOLARIZED LIGHT



B. TRANSMITTANCE OF OUTER (DOUBLE) PANE



C. TRANSMITTANCE OF INNER PANE

Figure III-13 Optical Characteristics of Standard Passenger Windows

6.2.1 Plexiglas Safety Cover

Approximately 3 cm clearance should be allowed between the cabin-side surface of an optical window and any equipment near this surface (e.g., cameras or telescopes) for a sliding 2.54 cm thick Plexiglas safety cover. This cover must either slide or pivot across the full aperture of the window and must be in place across the optical window during ascent and descent, and at all times when the optical window is not in use.

If any part of an experiment must project so as to hinder the motion of the safety window, a special safety window must be fabricated. Such a window would provide openings for protruding apparatus and would remain in place throughout the flight. The Airborne Science Office requires at least six weeks lead time for special safety window fabrication.

6.2.2 Mechanical Operations Near Windows

To preclude in-flight window fracture, mechanical operations, such as use of wrench, screwdriver, etc., carried out in the immediate vicinity of a window shall be performed with a safety window in place. Thus, proper clearances between the apparatus and the safety window must be provided if in-flight mechanical operations in this area are required.

6.3 ENVIRONMENTAL TESTING OF OPTICAL WINDOWS

Each window assembly, complete with frame and gasket, is subjected to the following tests prior to installation aboard the aircraft. First, the assembly is subjected to a pressure differential of 27 psi at room temperature for five minutes to check the pressure seal. Then, the assembly is subjected simultaneously to a pressure differential of 19.1 psi and to a temperature differential of 160°F for 20 minutes to check the structural integrity. The pressure and temperature conditions are then rapidly reduced to ambient room values.

To allow adequate time for testing, window assemblies should be at the Ames Research Center at least four weeks prior to the scheduled installation date. After testing, the window assemblies will be placed in bonded storage until such time as they are needed for installation into the aircraft. Window assemblies which have been altered in any way shall be retested prior to eventual installation and flight.

6.4 ANTI-FROST SYSTEM

Because of the low outside air temperature at the higher operating altitudes, cabin moisture may condense on the inside surface of single-pane windows. To prevent this, warm air supplied through a flexible duct from the cabin air conditioner is blown across the window. The exit air temperature at full flow is approximately 16°C under extreme outside ambient conditions. Since the cabin air is compressed from exterior ambient conditions, it exits from the flexible duct in a very dry condition (less than 5% relative humidity). However, dessicants may be inserted into the air stream if additional drying is necessary.

6.5 EXTERIOR WINDOW PROTECTION

Protection is not provided for the exterior surface of windows mounted in the special hatch, or for the exterior surfaces of the passenger windows. Therefore, in inclement weather or during ascent or descent through rain or clouds, exterior window surfaces may become wet. If water collects on the window during ascent, it may freeze and remain frozen during the entire flight. The windows may be kept clear of water while on the ground by covering with plastic sheeting.

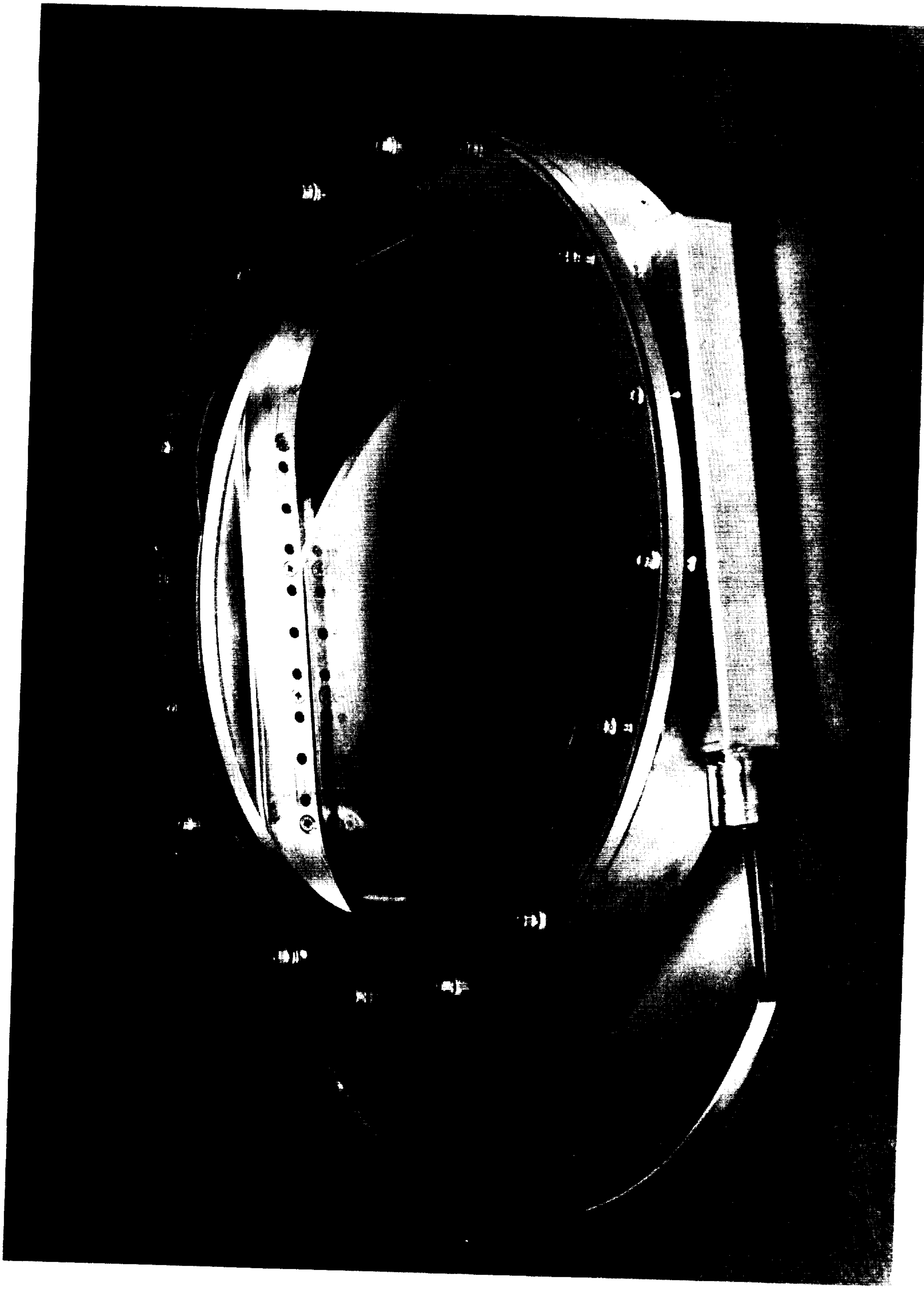
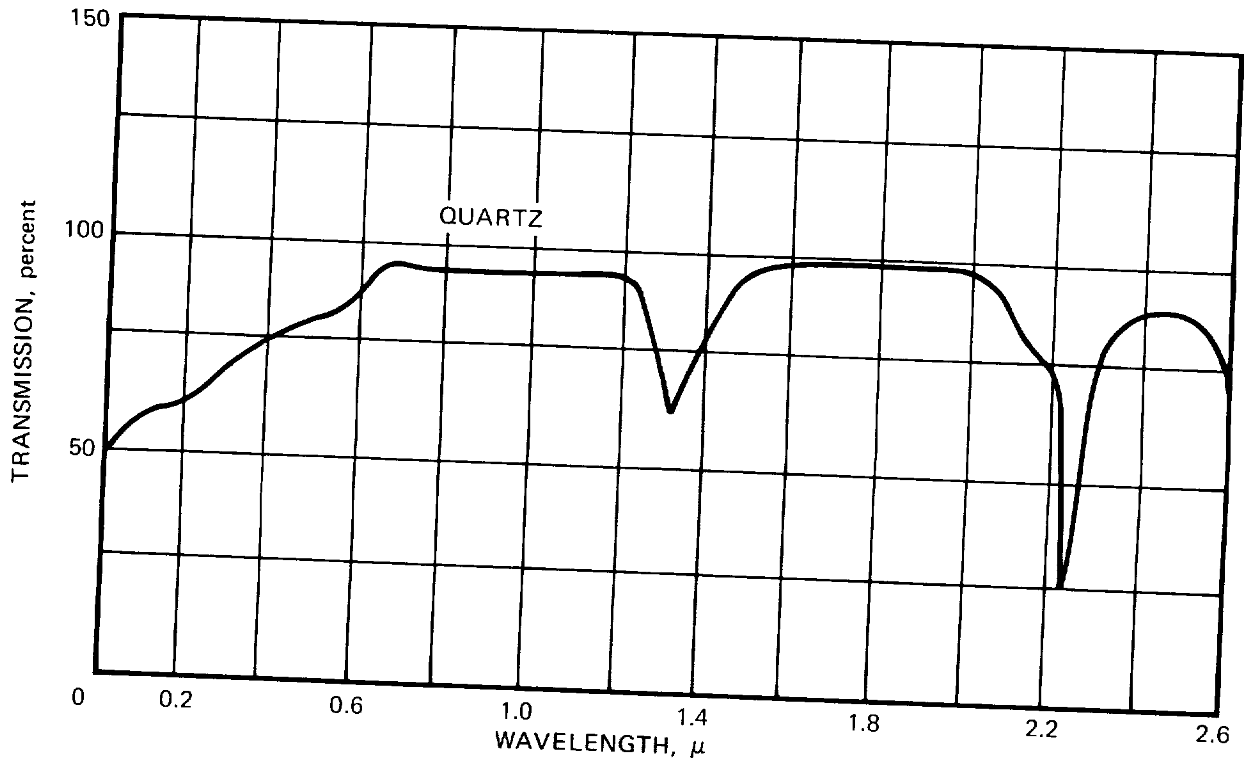


Figure III-14 Special Optical Window Hatch



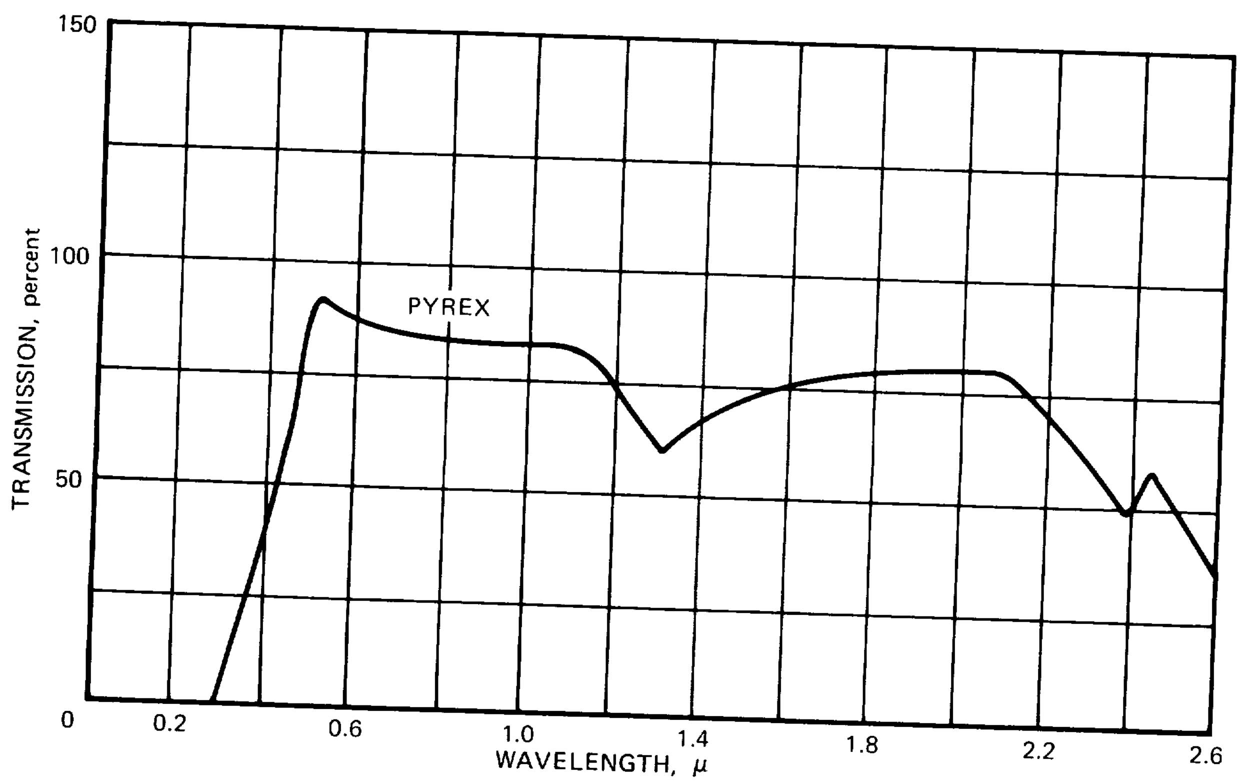


Figure III-15 Typical Transmission Curves for Quartz and Pyrex

7.0 ELECTRICAL FABRICATION

7.1 HIGH VOLTAGE ARCING

Ordinarily the cabin pressure at 13.7 km is equivalent to that at 2.4 km altitude. However, if the 30 cm telescope is being used, the proper pressure differential across the telescope requires cabin altitudes to be approximately 7.6 km. The reduced cabin pressure greatly enhances the possibility of arcing between high voltage components and ground. If a given voltage will arc over a gap length of x at sea level, then that same voltage will arc over a gap (of the same geometry) of length approximately $1.3x$ at 2.4 km, approximately $2x$ at 7.6 km and approximately $5x$ at 14.5 km pressure altitude. This should be taken into considerˑation by increasing lead separations, etc., or by potting high voltage components.

7.2 ELECTRICAL WIRING PRACTICES

Electrical wiring and soldering practices used for a ground laboratory often are inadequate or unacceptable for airborne programs. One of the most common problems Investigators encounter is broken solder joints. Such failures frequently delay or abort flight programs. Improper wiring or poor solder joints also could lead to electrical fire, even though the Investigator's equipment is adequately fused.

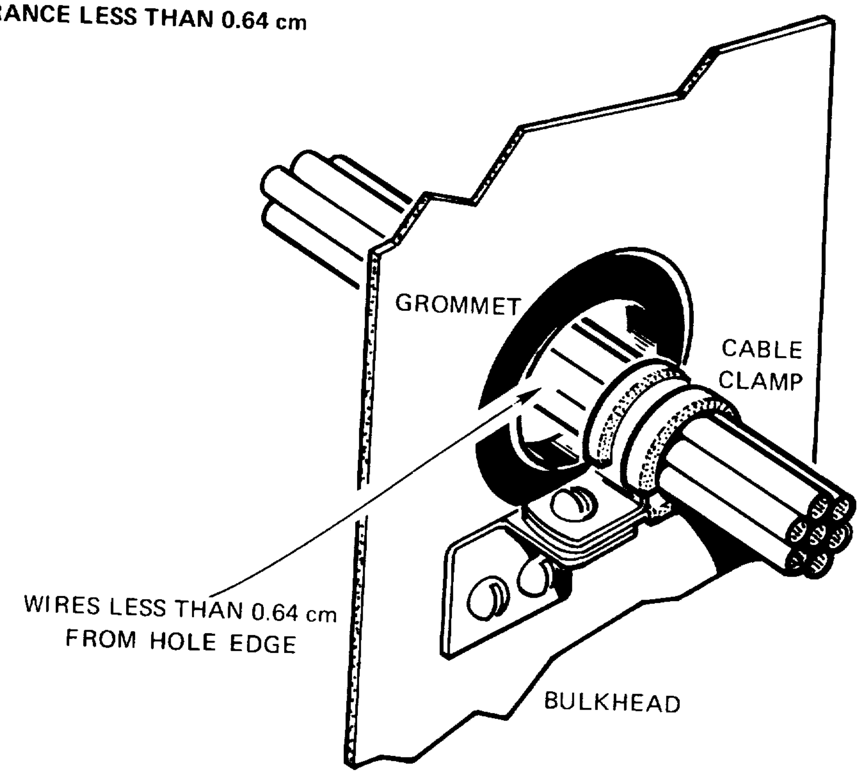
While there are a number of NASA and military specifications covering wiring of electronic components to be used on aircraft, it is realized that many electronic technicians may not be versed in working to these standards. Therefore, rather than force these exacting standards on the Investigator, a number of guidelines and techniques are provided in the following paragraphs to demonstrate acceptable wiring practices.

NOTE: *Investigator's electrical wiring is subject to inspection by cognizant Ames Research Center personnel prior to installation of equipment aboard the aircraft.*

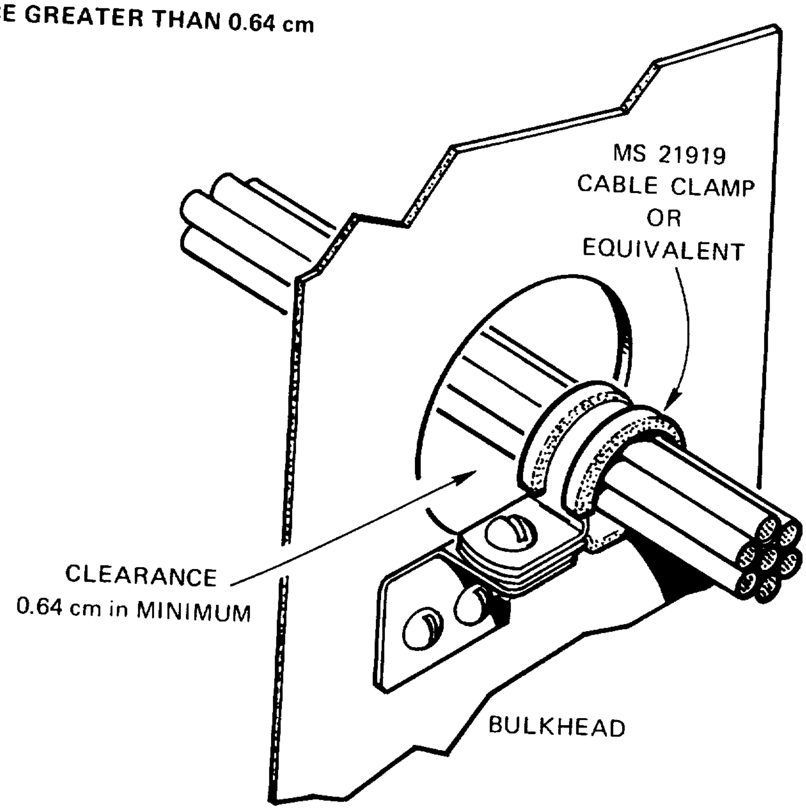
7.2.1 Aircraft Electrical Cable

Use aircraft-quality cable, Deltabestron No. SI 57403-BC, Alpha No. 1385, gauge No. 14 or larger. Correct cable selection is dependent upon knowledge of current requirements, operating temperatures, and environmental conditions involved in the particular installation:

A. CLEARANCE LESS THAN 0.64 cm



B. CLEARANCE GREATER THAN 0.64 cm



ANGLE BRACKET WITH TWO POINT FASTENING

Figure III-16 Protection Against Chafing of Electrical Insulation

a. Conductors

Copper conductors are coated to prevent oxidation and to facilitate soldering. Tinned copper or aluminum wire is generally used in installations where operating temperatures do not exceed 105°C. Silver-coated wire is used where temperatures do not exceed 200°C. Nickel-coated copper wire is used for temperatures up to 260°C. Nickel-coated wire is more difficult to solder than tinned or silver-coated wire, but by using proper techniques, satisfactory connections can be made.

b. Insulation

Polyvinylchloride (PVC) is a common insulation. It has good insulating properties and is self-extinquishing after the flame source is removed. Normal operating temperatures however, are limited to 105°C. Silicone rubber is rated at 200°C, is highly flexible, and self-extinguishing except in vertical runs. TFE Flourocarbon (polytetrafloroethylene) is widely used as high-temperature insulation. It will not burn, but will vaporize when exposed to flame. It is resistant to most fluids. FEP Flourocarbon (flourinated ethylene propolene) is rated at 200°C, but will melt at higher temperatures. Other properties of FEP are similar to TFE.

c. Thermal and Abrasion Resistant Materials

Glass braid has good thermal and abrasion qualities, but moisture absorption is high. Asbestos and other minerals provide high temperature and flame resistance, but are highly absorbent. Moisture absorption is reduced by use of silicone rubber, TFE, or other saturants. Nylon is widely used in low-temperature wires for abrasion and fluid resistance. Polyimide, a new material, has excellent thermal and abrasion resistant characteristics.

7.2.2 <u>Open Wiring</u>

Under certain circumstances electric wiring is acceptable for installation in aircraft without special enclosing means, and offers the advantage of ease of maintenance and reduced weight.

a. Cable Bundles

To simplify maintenance and to minimize the damage that may result from a single fault, limit the number of wires in the run. Shielded cable, ignition cable, and cables which are not protected by a circuit breaker or fuse usually are routed

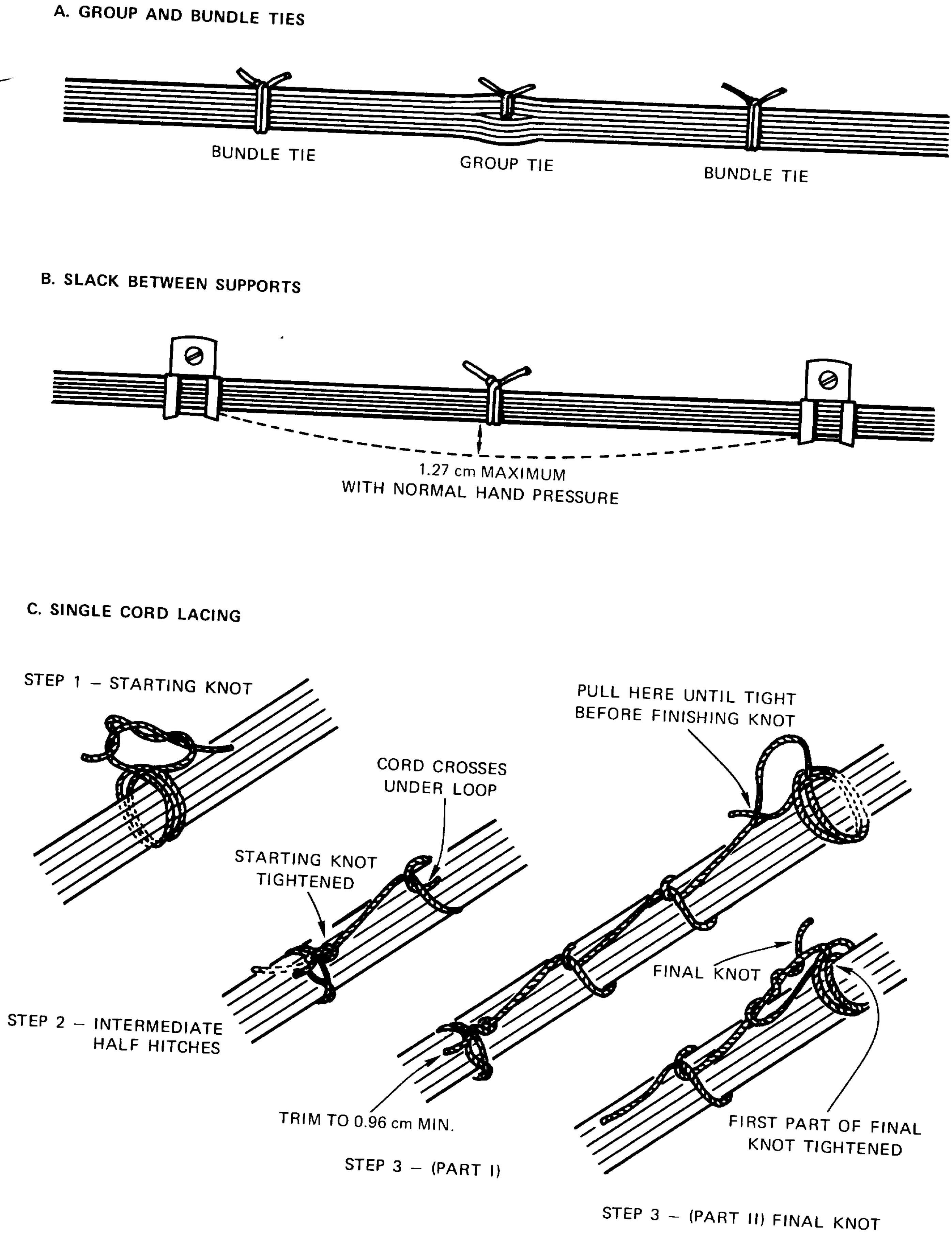


Figure III-17 Cable Tying Practice

separately. Avoid bending radii less than ten times the outer diameter of the bundle to prevent excessive stresses on the cable insulation.

b. Insulation Tubing

Soft insulating tubing (spaghetti) cannot be considered as mechanical protection against external abrasion of cable since at best it provides only a delaying action. Use conduit or ducting when mechanical protection is needed.

c. Clamping of Cable Bundles

Use clamps lined with nonmetallic material to support the cable bundle along the run. Tying may be used between clamps, but should not be considered as a substitute for adequate clamping. Adhesive tapes deteriorate with age and, therefore, are *not* acceptable as a clamping means.

7.2.3 Protection Against Chafing

Protect wire and wire groups against chafing or abrasion as damaged insulation may result in short circuits, malfunctions, or inoperative equipment. Support wire bundles using MS-21919 cable clamps and, when clamped in position, if there is less than 0.64 cm clearance between bulkhead cutout and the wire bundle, install a suitable grommet as indicated in Figure III-16. The grommet may be cut at a 45° angle to facilitate installation provided it is bonded in place and the slot is located at the top of the cutout.

7.2.4 Stripping Insulation

When stripping insulation remove no more material than is necessary. Stripping may be accomplished in many ways; however, the following basic principles should be practiced:

a. Make sure all cutting tools used for stripping are sharp.

b. When using special wire stripping tools, adjust the tool to avoid nicking, cutting, or otherwise damaging the strands.

7.2.5 Cable Terminals

Terminals specifically designed for use with the standard sizes of aircraft cable are available through normal supply channels. The tensile strength of the cable to one terminal joint should be at least equivalent to the tensile strength of the cable itself, and its resistance should be negligible relative to the

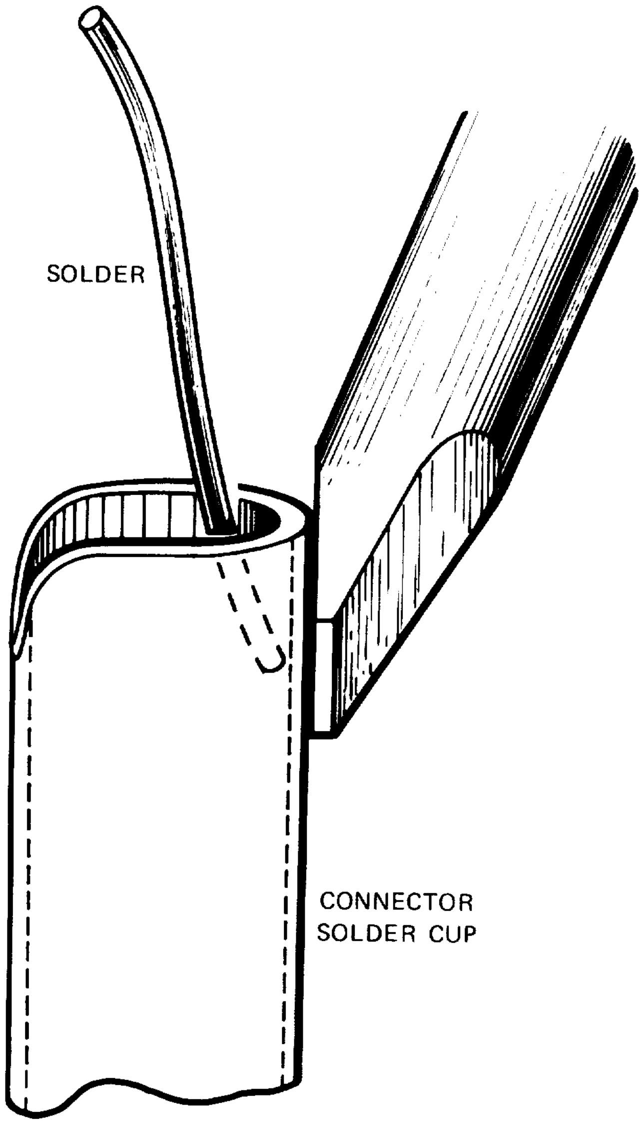


Figure III-18 Correct Solder Application normal resistance of the cable run. Use only approved aircraft quality terminals, some types of commercial terminals may lead to overheated joints, vibration failures and corrosion. The Facility Manager will assist in the selection of approved terminals.

7.2.6 Attachment of Terminals to Studs

Electrical equipment malfunction has frequently been traced to poor terminal connections at terminal boards. Loose, dirty, or corroded contact surfaces can produce localized heating which may ignite nearby combustible materials or overheat adjacent cable insulation to the smoking point.

7.2.7 Cable Routing, Tying, Lacing and Clamping

Support and route aircraft wiring and conduits to prevent relative movement within the aircraft and provide protection against chafing between wires or other objects and provide extra protection where wires or cables may be subjected to rough handling. Secure all wiring so it is electrically and mechanically sound and neat in appearance. Soft insulation tubing is not regarded as satisfactory mechanical protection against abrasion or considered a substitute for proper clamping or tying.

7.2.8 Wire Bend Radii

Wire bundles may consist of two or more groups of wires fastened or secured together, all traveling in the same direction. It is often advantageous to have a number of wire groups individually tied within the wire bundle for ease of identity at a later date, as shown in Figure III-17. To improve appearance and to minimize the possibility of insulation abrasion, arrange wire groups and bundles so the wires lie parallel to each other. Bends in wire groups or bundles should not be less than ten times the outside diameter of the wire group or bundle. However, a bend three times the diameter is acceptable to facilitate connections to terminal strips, provided the wire group or bundle is supported at each end of the bend.

7.2.9 Slack

Normally, wire groups or bundles should not exceed 1.27 cm deflection between support points, as shown in Figure III-17. This measurement may be exceeded provided there is no possibility of the wire group or bundle touching a surface that can cause abrasion. Sufficient slack should be provided at each end to:

a. Permit replacement of terminals

b. Prevent mechanical strain on wires

c. Permit shifting of equipment for maintenance purposes

7.2.10 Cable Tying and Lacing

Lace wire groups or bundles inside junction boxes or other enclosures. The single cord lacing method shown in Figure III-17 may be used for wire groups or bundles 2.5 cm in diameter or less. The recommended knot for starting the single cordlacing method is a clove hitch secured by a double-looped overhand knot as shown in Step 1 of Figure III-17.

Use wire group or bundle ties where the supports for the cable run are more than 30.5 cm apart. A tie consists of a clove hitch around the wire group or bundle secured by a square knot.

8.0 SOLDERING PRACTICES

Before starting the soldering operation, make sure that the soldering iron tip is clean, smooth and well-tinned. When resistance soldering equipment is to be used, make sure that probes are clean.

Whenever possible, make sure that the joint is mechanically secure before soldering. When this is not possible, as with MS connector contacts, make sure that the joint is held rigid during the cooling period.

Apply flux-core solder at the exact point between the metal and the soldering iron, as shown in Figure III-18 and hold the iron directly against the assembly. Melt the solder on the joint, not on the iron, placing the soldering iron firmly against the junction. If heavy rocking pressure is necessary, either the iron does not have sufficient heat capacity for the job, or it has not been properly prepared, or both. Do not apply heat to the work any longer than the time necessary to melt the solder on all parts of the joint.

Use only as much solder as necessary. Do not pile up solder around the joint; this is wasteful, and results in joints difficult to inspect. Care should be exercised with silver-coated wire to prevent wicking during soldering application.

When the soldering iron is not in actual use during operations, keep it in a holder, This will protect the operator against burns, and the iron against damage.

Do not allow the iron to overheat. Disconnect the iron when it is not in use between operations, or use a heat-dissipating stand which will keep the iron at a constant temperature.

When a solder joint has been made, hold the work firmly in place until the joint has set. Disturbing the finished work will result in a joint mechanically weak, and with high electrical resistance. Allow solder joints to cool naturally. Do not use liquids or air blasts.

If the correct amount of solder is used and procedure instructions followed carefully, there should be little or no excess flux remaining on the finished joint. If cleaning is necessary, remove excessive flux by brushing the joint with a stiff brush dipped in methyl alcohol, methyl isobutyl ketone or a similar approved solvent. Use alcohol sparingly and avoid contact between alcohol and wire insulation. For cleaning printed circuit connections, use a cotton-swab stick for small areas and a lint-free clean cloth for large areas and board edges.

A good soldered joint will have a bright silvery appearance, with smooth fillets and feathered, not sharp edges. The entire joint will be covered with a smooth, even coat of solder, and the contour of the joint will be visible.

Any of the following indicate a poor solder joint, and are cause for rejection:

a. Dull gray, chalky, or granular appearance; evidence of a cold joint

b. Hairline cracks or irregular surface; evidence of a disturbed joint

c. Grayish, wrinkled appearance; evidence of excessive heat

d. Partially exposed joint; evidence of insufficient solder

e. Scorched wire insulation or burned connector inserts

f. Globules, drips or tails of solder

If any of the above are present in a finished solder joint, the joint should be taken apart, parts cleaned, and the entire soldering operation repeated using fresh solder.

NASA LEARJET AIRBORNE OBSERVATORY

INVESTIGATOR'S HANDBOOK

SECTION IV

OPERATING PROCEDURES

1.0 OPERATING PROCEDURES

1.1 PERSONNEL QUALIFICATIONS FOR FLIGHTS ABOARD THE LEARJET

Investigators who fly aboard the Learjet Airborne Observatory must be in good health. Persons with heart disease, diabetes, or chronic respiratory ailments, or persons with colds or sinus conditions will not be allowed to participate in research flights at extended altitudes. Without exception, the Ames Research Center Airworthiness Review and Flight Safety Board requires that Investigators who plan to fly above 42,000 ft (12.8 km) have the *equivalent* of a current FAA Class II flight physical certificate, an electrocardiogram (EKG), and a current high-altitude certificate.

The requirements for the Class II physical may be obtained from any FAA office. The high-altitude certificate requires training in the use of oxygen masks and other equipment, recognizing and treating anoxia and hyperventilation, and a low pressure chamber test. A one-day high-altitude training course and a pressure chamber test are given at several U. S. Air Force and U. S. Navy installations throughout the country. Arrangements for the course may be made through the Airborne Science Office. Contact the Facility Manager for assistance in arranging for these tests.

Investigators who are to engage in flights above a) 42,000 ft (12.8 km) or b) a cabin altitude of 14,000 ft (4.3 km) will be required to have an examination by the Ames Research Center Health Unit immediately prior to beginning the series of flights. The written results of this examination must be submitted to Flight Operations and approved before permission to fly is granted. Facial hair should be kept to a minimum. *Beards, mutton-chop sideburns, or large mustaches are specifically not allowed for personnel on these high altitude flights.* The reason for this requirement is that there must be positive contact between oxygen masks and facial skin without intervening hair.

1.2 SAFETY CONSIDERATIONS

Each occupant of the Learjet must be restrained during takeoff and landing such that he cannot be thrown against hard objects by unusual aircraft motions. Leg room must be sufficient to allow sitting against the seatback without twisting the spine. If the baggage compartment is being used for experimental apparatus and one or more of the aft bench seats is occupied during takeoff and landing, the occupied seat(s) must have the back in place.

The Learjet cabin has two exits that can be opened from the inside. The regular passenger door has a clam shell action and opens in two steps: (1) the handle on the upper section is swung out and up, (2) the recessed handle on the lower section is lifted and rotated clockwise to the *open* recess. The knobbed cable at the left end is pulled out (up), the catch at its base released and the section lowered by diminishing the upward force on the cable. If rapid egress is desired, the lower section may be left in place and exit made through the upper opening alone.

The second exit is an emergency hatch located over the right wing as shown in Figure I-5. This hatch is opened by grasping the handle at its top and pulling inward. Mounted equipment must not impede ingress or egress through this exit or between the cockpit and this exit.

A fire hazard exists when petroleum products are exposed to pure oxygen. During high altitude Learjet flights the breathing of pure oxygen is mandatory, so the use of materials such as lip ice (e.g., Chapstick, mustache wax, etc.) on surfaces directly exposed to oxygen must be avoided.

Access to the valves and filler connections to the two oxygen bottles in the aft section of the baggage compartment must be available at all times. The location of the valves and filler connections are shown in Figures III-7 and III-9.

1.3 FREQUENCY OF FLIGHTS

Each Investigator is usually aboard the Lear for a two or three week period. If the experiment is being integrated on the Learjet for the first time, the Investigator should reserve a two-week period before the anticipated data flights to allow for resolution of equipment problems. Typically, the first week is spent installing the equipment and the second week flying. The first flight is normally a daylight flight for equipment checkout and acclimatization of the Investigators to the Learjet environment. Pilots are generally available Monday through Thursday evenings on a 24-hour basis. Flights are not normally made on Friday, Saturday or Sunday. *Usually one flight of 2 1/2 - 3 hours duration is made during a 24-hour period.* A ground crew is available to assist the Investigator from 0700 to 2400, Monday through Friday. If flights are anticipated at other than these hours, the Investigator should notify the Ames Research Center at least one week in advance.

NASA LEARJET AIRBORNE OBSERVATORY

INVESTIGATOR'S HANDBOOK

S E C T I O N V

PROPOSAL PROCEDURES

1.0 GENERAL DESCRIPTION

The National Aeronautics and Space Administration welcomes proposals from any domestic or foreign scientist who desires to use the NASA Learjet Airborne Observatory for astronomical research, or who desires to develop an instrument necessary for a specific airborne research program.

1.1 PROPOSAL GUIDELINES AND CONSTRAINTS

Two types of proposals are suggested herein. Respondents may propose for one or both types. A separate proposal should be submitted for each scientific program.

1.1.1 Type 1: Research Requiring Development of New Instruments

Many research programs will require the development of new or unique instrument systems in order to fulfill scientific objectives. Proposals requesting NASA support for the development of these systems must be strongly justified by the scientific merit of the research for which the system is intended. NASA encourages groups with similar interests to collaborate since funds may be limited and duplication normally will not be possible. As instruments developed under NASA grants or contracts become operational, they will be assigned in most cases to the Learjet Airborne Observatory and subsequently be made available for use by other qualified observers.

1.1.2 Type 2: Research Using Existing or Planned Instrumentation

Proposals in this category should be for observational programs which can use the respondents' own existing equipment or instrumentation belonging to the Learjet Airborne Observatory.

1.2 PROPOSAL CONTENT

Proposals submitted in response to this announcement should contain the following material assembled in the order given:

1.2.1 Technical

a. Cover Letter: Each proposal should be prefaced by a cover letter signed by an official of the Investigator's organization who is authorized to commit the organization to the proposal and its content.

b. Title Page: The title page should contain the following:

(1) A short descriptive title for the proposed investigation
(2) Name of proposing organization(s)
(3) Names, full addresses, *telephone numbers*, and affiliations of all principal Investigators
(4) Date of submission

c. Summary or abstract: The title page should be followed by a concise statement of what the proposed investigation is, how it will be performed, the anticipated results, *and a table listing specific characteristics of the instrument (wavelength range, resolution, filter pass band, detector, etc.).*

d. Background and justification: A description of the research work that motivates the proposal and a statement demonstrating the need for the proposed investigation. This section should specifically describe how the Investigator expects the Learjet Airborne Observatory to help in solving experimental problems in his field of interest.

e. Objectives and major requirements: A brief statement of what the proposed experiment is designed to accomplish and what technical requirements must be met to insure success of the experiment.

f. Approach:

(1) Concept of the investigation
(2) Method and procedures for conducting the experiment
(3) Performance criteria for success of the experiment
(4) Supporting studies involved in the investigation
(5) Plans for post-flight evaluation of experimental data

g. Ground support and logistical requirements.

h. Expected results: A general indication of the results expected from the investigation if successful, and their implications for the Investigator's field of study.

1.2.2 Management

a. Work Plan

(1) Program management plan, giving the names of the persons responsible for carrying it out
(2) Names, addresses, and experience and education resumes of the program's key scientific and management personnel

(3) Performance schedule, indicating manpower requirements and lengths of time needed to complete specific phases of the proposed work

b. Cost Plan (United States Proposals Only). If NASA funding support is required, a cost plan containing the following must be submitted:

(1) Cost estimates for direct labor, including individual manhours and rates for the personnel involved
(2) Estimated costs for materials
(3) Travel costs
(4) Overhead and general and administrative costs, with descriptions of the method of their calculation and the method for applying them to labor and other costs
(5) Other costs (to be explained)
(6) A quarterly spending curve keyed to the work schedule
(7) Total cost

1.3 ADDITIONAL PROPOSAL INFORMATION

NASA Handbook, NHB 8030.1A, *Opportunities for Participation in Space Flight Investigations*, dated April 1967, contains further general information on preparation of proposals for space experiments. This handbook is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151 (No. 75724).

1.4 PROPOSAL ROUTING

Copies of each proposal should be submitted as follows:

a. Proposals from all United States sources other than NASA: The official proposal and one copy to:

Office of University Affairs
Code PY
National Aeronautics and Space Administration
Washington, D. C. 20546

b. Proposals from foreign sources: Proposals for participation by individuals from outside the United States should be sent first to the official national agency of their country responsible for space and/or scientific activities. After review, that agency should forward endorsed proposals to the NASA Office of International Affairs (Code I), Washington, D. C. 20546, after which they will go through the same evaluation and selection procedure as United States originated proposals.

Proposals should be submitted in English. Should a proposal be selected, NASA will arrange with the sponsoring national agency for the proposed participation on a cooperative (no exchange of funds) basis, in which NASA and the foreign sponsoring agency will each bear the cost of discharging their respective responsibilities. Informal copies of the proposal may be sent directly to NASA.

c. Proposals from *all* sources: Ten copies to:

Mr. Robert M. Cameron
Airborne Science Office (M. S. 211-12)
Ames Research Center
Moffett Field, California 94035

Telephone: (415) 965-5338

and three copies to:

Mr. Michael E. McDonald
Code SG
National Aeronautics and Space Administration
Washington, D. C. 20546

Telephone: (202) 755-3616

1.5 PROPOSAL ACCEPTANCE

NASA acceptance of any proposal involving use of the Learjet Airborne Observatory requires adherence to the guidelines and constraints presented in this Investigator's Handbook.

NASA LEARJET AIRBORNE OBSERVATORY

INVESTIGATOR'S HANDBOOK

S E C T I O N VI

REFERENCE DATA

REFERENCE DATA

The material contained in this section has been inserted to provide to the Investigator a readily-available source of useful data. It is planned that material of interest will be added to the Handbook from time to time. Investigators are encouraged to recommend data which would be of use to them for inclusion herein. Suggestions may be made to the Learjet Manager or Facility Manager at any time.

REFERENCE A

NASA-AMES FOA:211-3
Moffett Field, California
September 10, 1974

AIRWORTHINESS ASSURANCE OFFICE REPORT

Report No.: 365-001

Prepared By: R. Davidson

Aircraft: Learjet 365

Activity: Test of Experimenter's Rack (Ref. Drawing No. 5234026)

The subject rack was tested to destruction on September 4 with the following people present; R. Mason, SSO; V. Nespolo, Northrop; A. Campbell, RFE; and R. Davidson, FOA.

The results of the test are very favorable with the original design goal. The maximum total weight the experimenters shall load into the rack is 188 pounds. The maximum overturning moment is limited to 2726 inch-pounds measured from the lower edge of the equipment bay. Therefore, the c.g. at maximum weight shall be = 14.5 inches from the bottom of the equipment bay.

The test was conducted in the hanger using a wide-flange column as the test fixture support. The fixture consisted of a steel plate, 1/2" thick x 16" wide x 36" long with lugs welded on to simulate the Learjet floor rails. The rack was mounted on the fixture; then the fixture was C-clamped to the vertical beam. The static load was supplied in the form of lead bricks each weighing 26 pounds. Three trays were put into the rack to distribute the load from the forward corner posts to the rear posts. The trays were spaced 10" apart. 1" thick plywood was installed on the "forward" (down) corner posts between the trays. The lead bricks were then placed on the plywood in the following sequence: 3 bricks in the "lower" bay, 2 bricks in the "middle" bay and one brick in the "upper" bay. This had the effect of working up to the maximum overturning moment. The "lower" bay was filled completely just prior to rack failure. The loading and deflections were as follows:

Lower bay c.g. @ 7.75"	Middle bay c.g. @ 17.75"	Upper bay c.g. @ 27.5"	Deflection Inches
15 bricks	10 bricks	5 bricks	11/16
18 "	12 "	6 "	13/16
21 "	14 "	7 "	1
24 "	16 "	8 "	1 1/4
27 "	18 "	9 "	1 1/2
30 "	20 "	10 "	1 13/16
32 "	22 "	11 "	2 1/2

Two more bricks were placed in the "middle" bay and the rack collapsed.

The manner of failure appeared to be that each tray separated from the rear posts by shearing around the attaching screws allowing all the load to be applied to the forward posts whereupon the rack failed.

It should be noted that panels simulating instruments faces were not installed during the tests.

Also, an extra margin of safety may be easily and inexpensively obtained by using fillers under the screw head on the aft side of the rack when mounting trays.

Total load and overturning moment was determined in the following manner:

a. No. of bricks = 65 just prior to failure

b. Weight of one brick = 26 lbs.

c. Total weight on rack = 65 x 26 = 1690 lbs.

d. Allowable rack load = $\frac{65 \times 26}{9 \text{ g's}}$ = 188 lbs.

e. c.g. location = $\frac{(32 \times 7.75) + (22 \times 17.75) + (11 \times 27.5)}{65}$ = 14.5 inches

/s/ R. Davidson

Concurrence: /s/ B. E. Cunningham
Chief, Airworthiness Assurance Office

NASA TECHNICAL
MEMORANDUM

NASA TM X-62,389

NASA TM X-62,389

LEAR JET TELESCOPE SYSTEM

E. F. Erickson
D. Goorvitch
M. G. Dix
M. J. Hitchman

Astrophysics Branch
Space Science Division
Ames Research Center
Moffett Field, California 94035

September 1974

TABLE OF CONTENTS

PREFACE

The telescope described in this document was patterned after the original "Flying Infrared Telescope" developed by F. J. Low, H. H. Aumann, and C. M. Gillespie. The present instrument was designed as a multi-user facility for observations of celestial objects at infrared wavelengths, where ground-based observations are difficult or impossible due to effects of telluric atmospheric absorption. The telescope is mounted in a Lear Jet model 24B which permits typically 70 min. of observing per flight at altitudes in excess of 13 km (45,000 ft, figure 1). The facility is managed by the Airborne Science Office at the National Aeronautics and Space Administration's Ames Research Center, Moffett Field, California.

The telescope was developed at Ames by personnel of the Astrophysics Branch with assistance of personnel from the Research Facilities and Instrumentation Division and the Technical Services Division. The cooperation of Prof. Low, Mr. Gillespie, and Dr. D. A. Harper who used the original telescope, is gratefully acknowledged.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

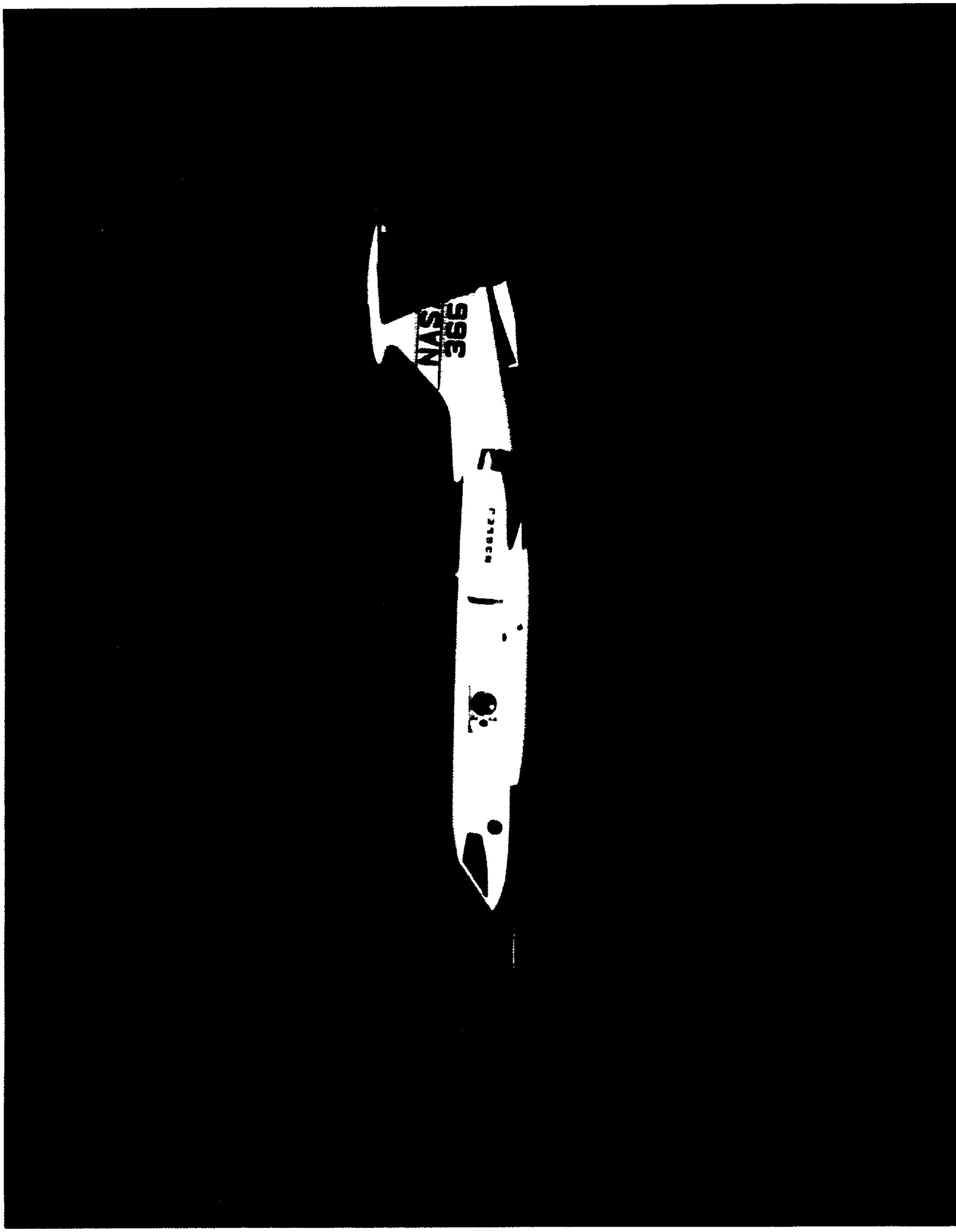


Figure 1.—The Lear Jet in flight.

I. Description of the Telescope

A. Introduction

This telescope is a Dall-Kirkham Cassegrain configuration. As such the primary is an ellipsoidal mirror and the secondary is a spherical mirror. The primary mirror is made from Cervit and coated with aluminum plus an overcoating of silicon monoxide. There are several secondary mirrors made of Silicon, Cervit, and Aluminum. The maximum useful diameter of the primary is 30 cm (12 in.).

The secondary mirror can be made to oscillate about the vertical axis of the telescope. An on-axis detector then observes two adjacent parts of the sky called right beam and left beam. The secondary mirror, driven by a pair of solenoids, oscillates back and forth from right beam to left beam at frequencies up to about 100 Hz. A chopper-driver circuit is available, providing frequencies of about 15, 30, 48, 70, and 95 Hz. A separate input connector allows one to set the chopping frequency by an external oscillator. The throw on the oscillating secondary can be adjusted manually up to about 15 arc min on either side of the vertical axis of the telescope.

The telescope is mounted in the Lear jet at a mean elevation of 20° above the horizon. A variable angle adapter permits operation of the telescope from 13° to 28° in elevation. The telescope has ±3° of gimballed, gyro-stabilized motion both in the roll direction (elevation) and the yaw direction (azimuth). An additional motion of up to 2° can be obtained in roll by flying with the wing up or down. In the yaw direction additional motion can be obtained by turning the plane right or left. An air seal near the front of the telescope leaks cabin air when the aircraft is pressurized to permit free motion of the telescope in the gimbals. A schematic view of the telescope is shown in figure 2 and a photograph of the telescope in the cabin is shown in figure 3.

In a typical flight pattern the object appears at the beginning of an observation either high in roll (for a setting object) or low in roll (for a rising object). The pilot then flies the jet in a predetermined flight plan keeping the yaw axis in its midrange while the object traverses the roll direction from $(20 \pm 8)^\circ$ to $(20 \mp 8)^\circ$. Thereafter the object is out of the field of view of the telescope terminating the observation.

Sighting is done with an auxiliary telescope designated as the guide scope. This telescope has a reticle to assist in guiding the telescope. The two available reticle patterns are shown in figure 4. The total field of view as seen in the guide scope is about 5°. The guide scope has two optical adjustments, one to position the reticle at the focus of the objective, the other to focus the eyepiece on the reticle. The alignment of the guide scope relative to the main telescope can be varied mechanically to provide a convenient "boresight", i.e., correlation between the detector and guide-scope image fields.

B. Telescope Guidance System

The telescope is held fixed in inertial space in two axes by two torque motors. The two controlled axes of the telescope correspond to roll and yaw of the airplane. The attitude of the telescope in inertial space is sensed by two gyroscopes. An electronics stabilization system senses the gyro outputs and drives the torque motors. The telescope may be pointed in any direction perpendicular to the plane defined by the roll and yaw axes.

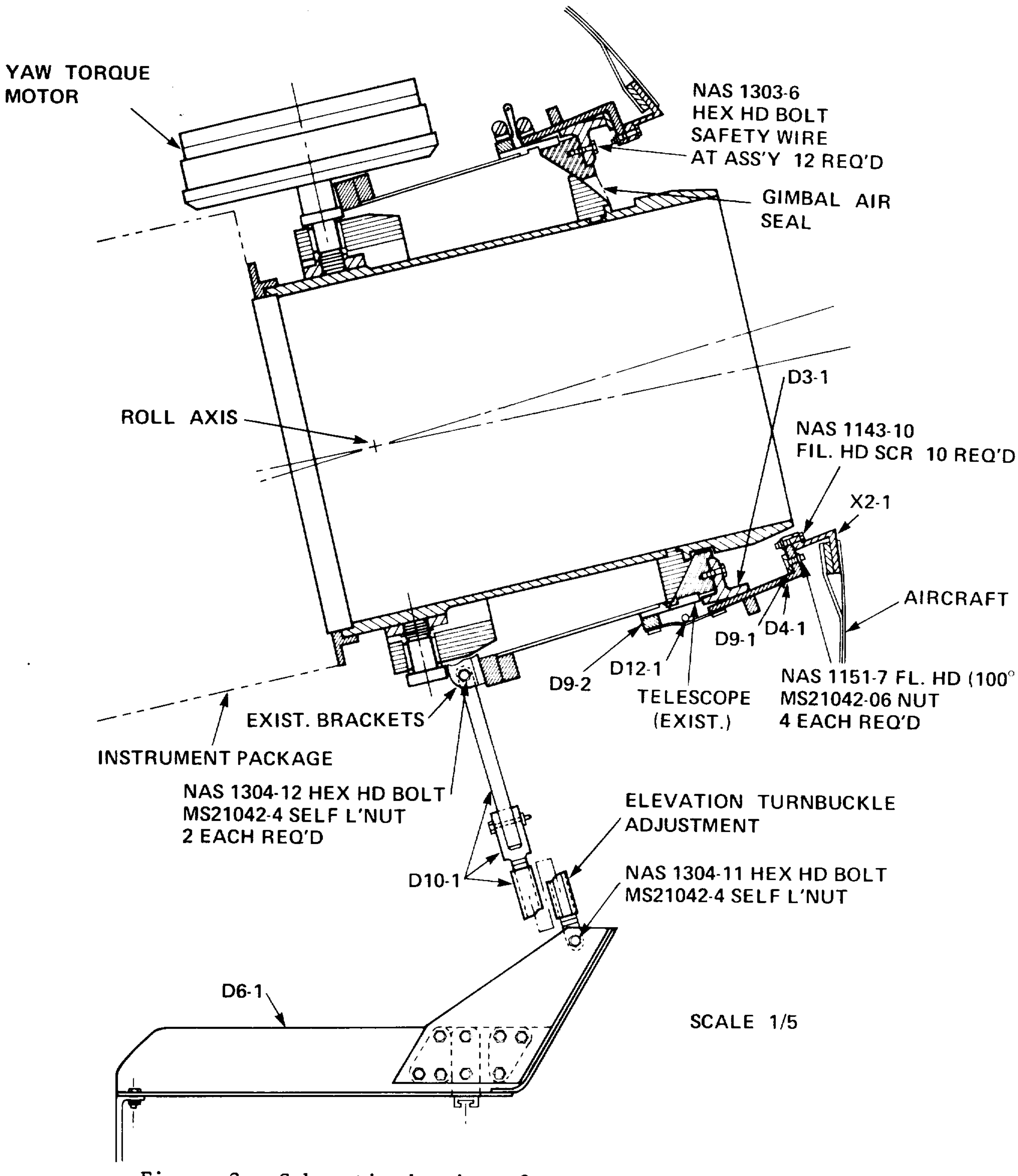


Figure 2.— Schematic drawing of telescope in place.

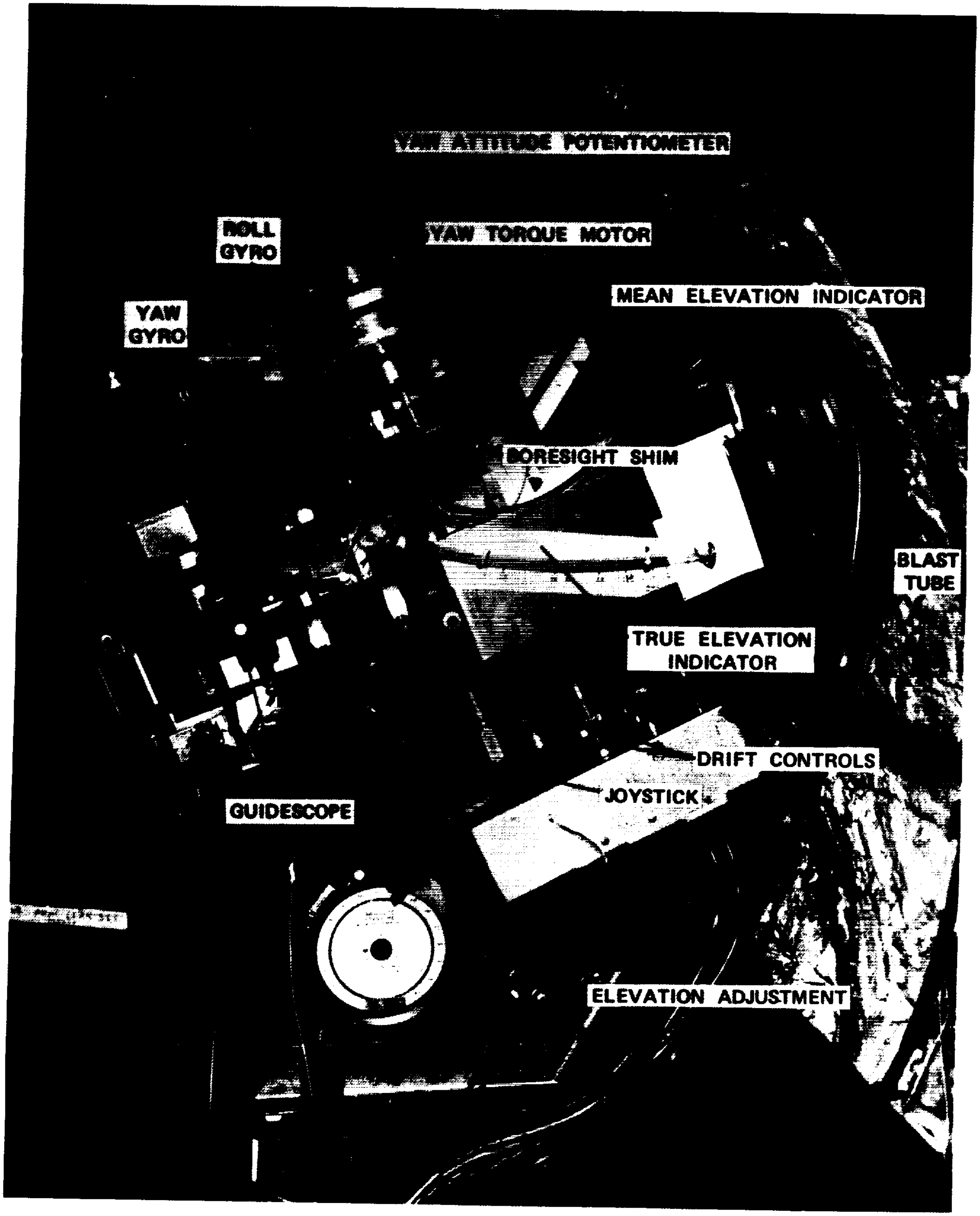


Figure 3.— Lear Jet telescope: interior view of aircraft looking aft on left side.

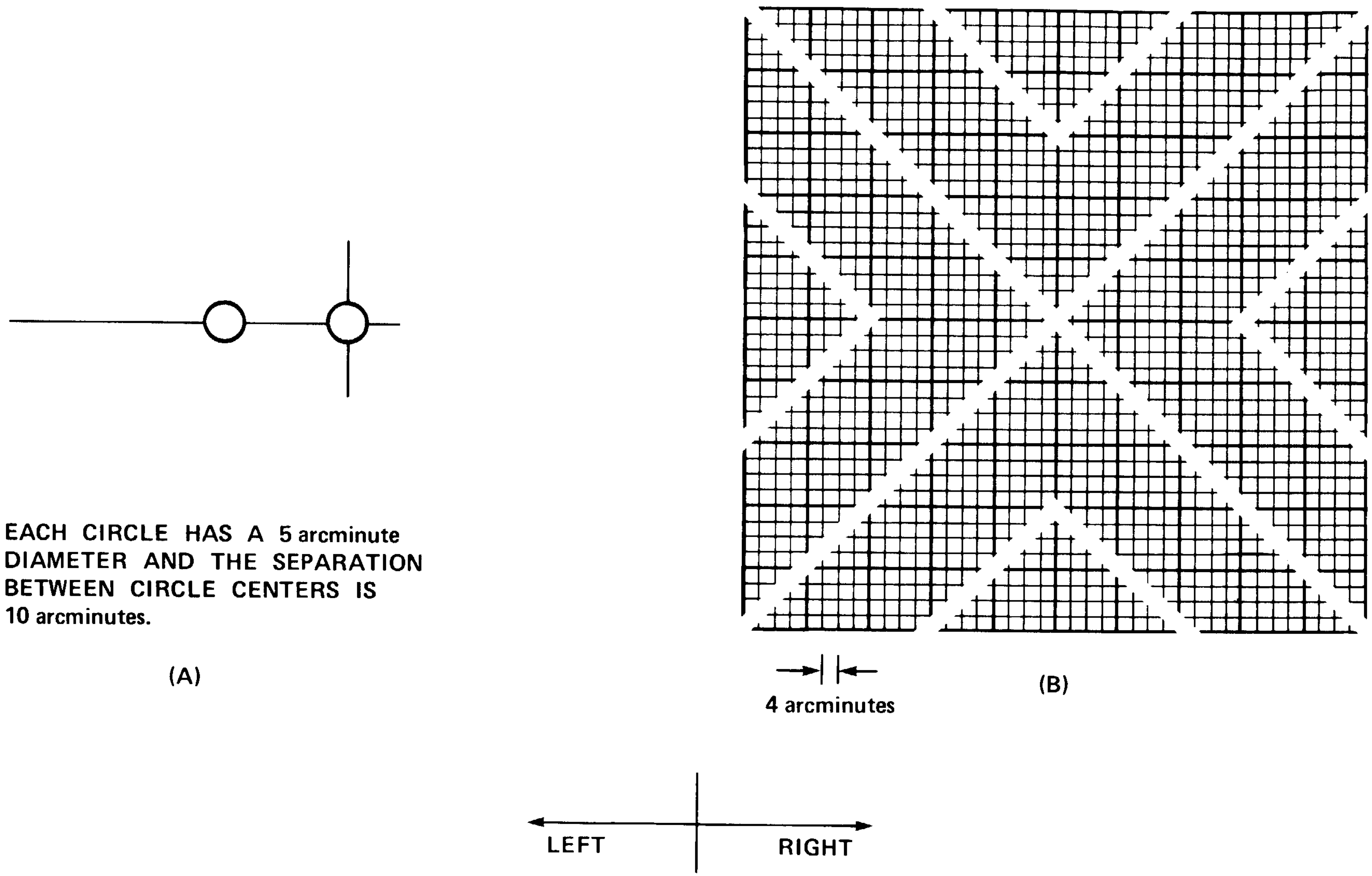


Figure 4.— Available recticle patterns.

The mechanism for controlling the motion of the telescope manually is a "joy stick" which electronically overrides the gyroscope signals. The joy stick responds to the pressure applied, the greater the pressure the faster the telescope moves. This pressure-sensitive joy stick does not move when pressure is applied.

On the front panel of the gyroscope telescope-stabilization electronics package are two controls for each axis - the phase and gain for adjusting the servo-system parameters. Drift controls on the joy stick box may be used to null out any large drift and one can obtain drift rates as low as one arcminute per minute with a pointing stability of ±1 arcmin.

C. Instrument Compatibility

There is a 6.35 cm (2.5 in.) diameter hole in the primary mirror permitting the radiation to be coupled to a measuring device. The measuring instrument that can be used on the back of the telescope can be almost of any variety. However, the following physical dimensions should be kept in mind.

The telescope has a 38.1 cm (15 in.) diameter back plate. In this plate are two sets of 1/4-28 NF blind-tapped holes for securing an instrument package. The first set of holes consists of 12 holes on a 29.21 cm (11.5 in.) BCD. The second set of holes consists of 6 holes on a 10.16 cm (4 in.) BCD. The back plate and all pertinent dimensions are shown in figure 5. Care in instrument design is required to avoid the three screws on a 30.48 cm (12 in.) BCD on the back plate which retain the primary mirror. The instrument must also clear the yaw torque motor, (see figures 2 and 3) and permit mounting the yaw gyro on the back plate.

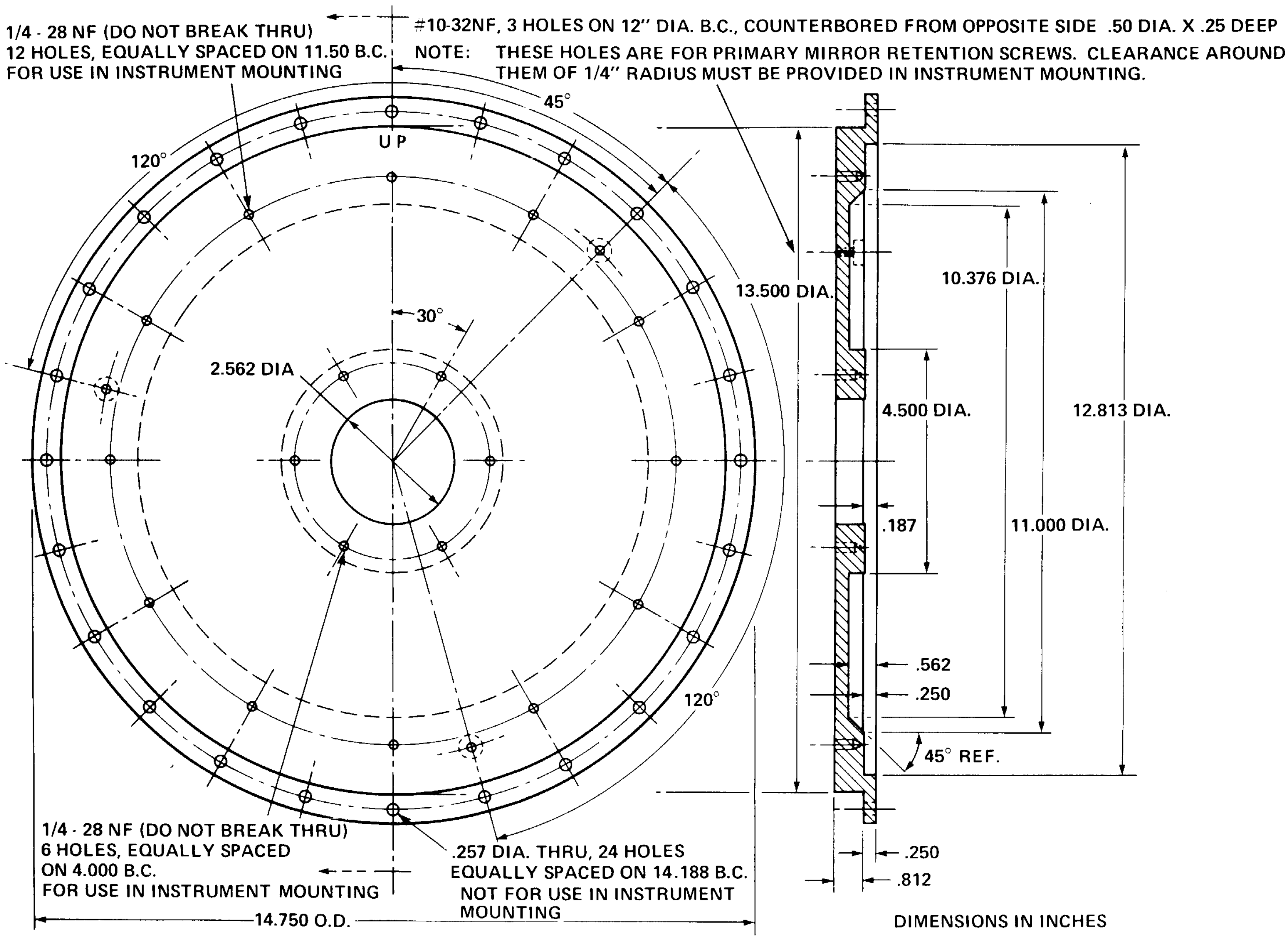


Figure 5.— Telescope backplate.

The maximum torque relative to the roll axis allowed for an instrument package is about 6.8×10^8 dyne-cm (600 in.-lb). The weight of the instrument package must be offset by counterweights leaving the telescope balanced.

D. Auxiliary Equipment

There is a wheeled cart for testing the telescope out of the aircraft.

A collimated light source for testing the instrument can be mounted in the telescope barrel. The lamp used is a T-1 subminiature incandescent lamp 715 manufactured by Chicago Miniature Lamp Works. The electrical characteristics of this lamp are: V = 5 volts, I = 0.115 amperes, approximate temperature = 2100° K.

A 35.56 cm x 45.72 cm (14 in. x 18 in.) mirror mounted on a tripod is available. This permits looking at ground-bound objects for focusing and boresighting when the telescope is mounted in the aircraft.

A circuit for driving the oscillating secondary mirror is available. This is shown in figure 6. This chassis contains two voltage-to-frequency converters for use in recording DC signals on an FM tape recorder, in addition to the chopper driver circuit.

An eyepiece adapter is also available. This adapter fits into the 6.35 cm (2.5 in.) diameter hole in the backplate. The adapter can be adjusted to position the reticle of the eyepiece at the desired focal plane. The adapter may also be used to focus the telescope. This procedure is described in section III. E.

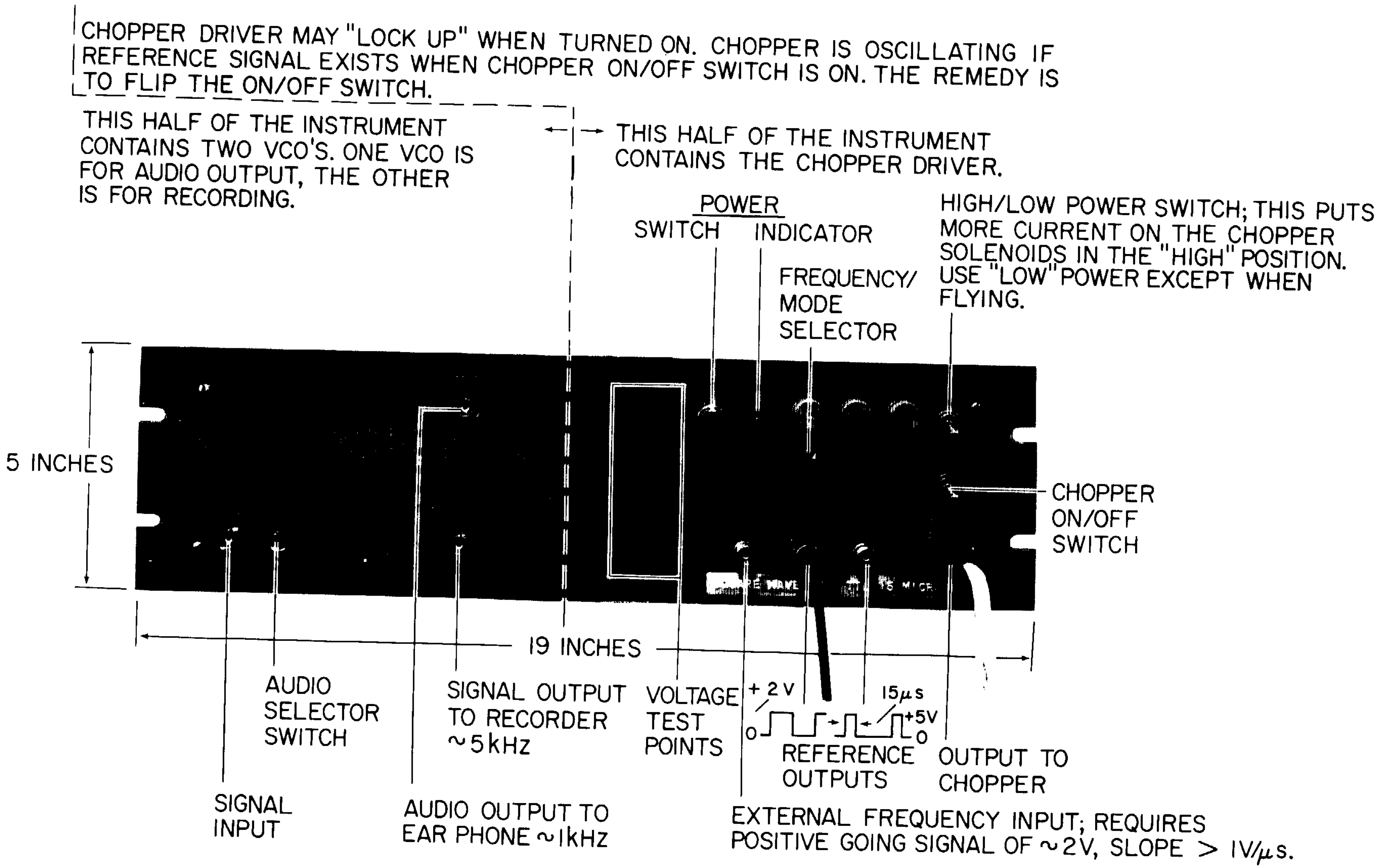


Figure 6.– Available chopper driver and voltage-to-frequency converter electronics.

II. Telescope Guidance Installation

A. Mounting the Telescope

The telescope attaches to the Lear Jet fuselage just aft of the entrance. A bolt mounting circle on the telescope mates with a similar hole pattern in an adapter plate on the fuselage. The elevation turnbuckle adjustment mounted between the floor of the cabin and the rear of the telescope provides further support for the telescope.

Mounting procedure for the telescope:

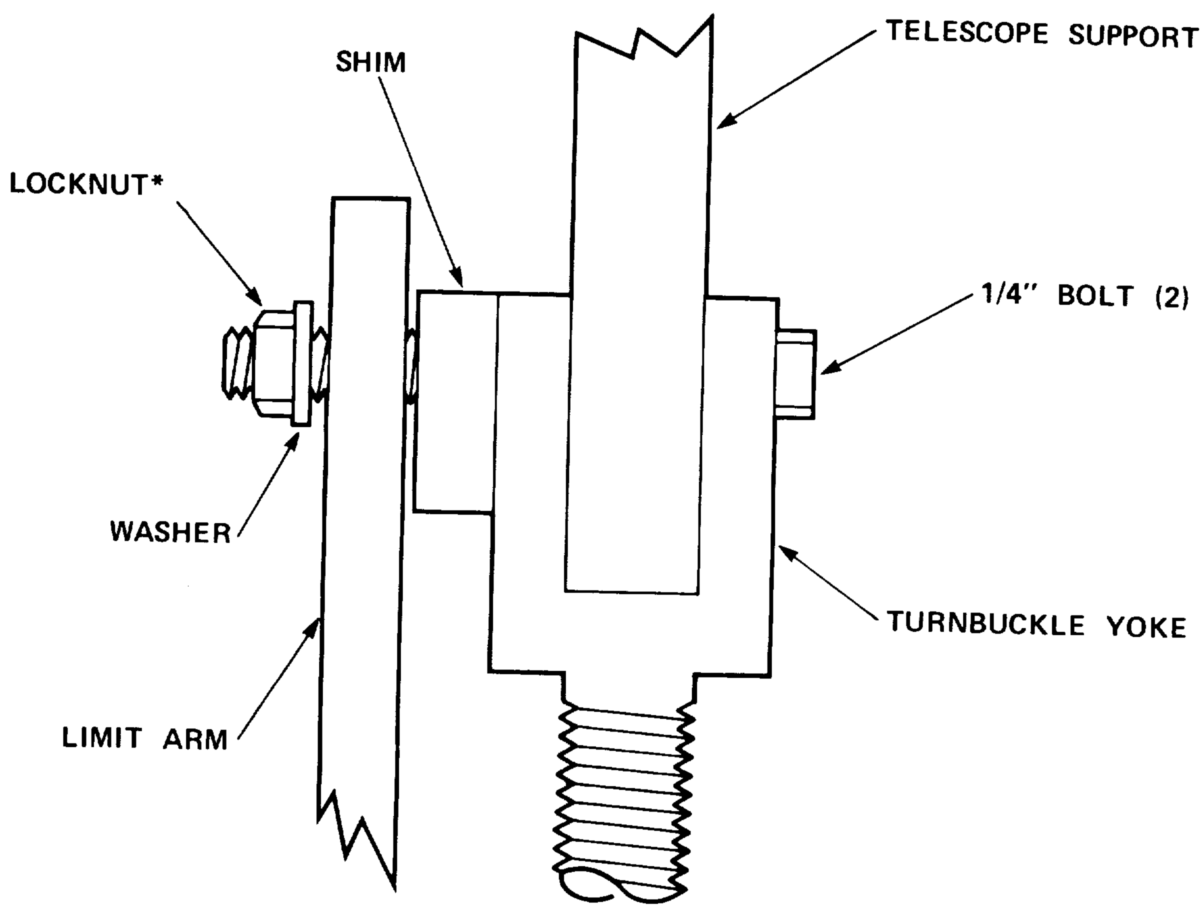
1. Engage two guide bolts on telescope with mounting plate.*
2. Attach elevation turnbuckle support bracket between cabin floor and telescope.
3. Using NAS 1143-10 screws complete mounting plate assembly.*
4. Complete assembly of turnbuckle support (see figure 7).
5. Mount the joy stick box on its bracket (optional).
6. Operate the turnbuckle and gimbals to verify that the telescope has an unrestricted total elevation range from 13° to 28°.

B. Installation of the Electronics

The telescope Giudance Unit, figure 8, mounts in the bottom of a rack just opposite the entrance, or on the floor between the door and the telescope, or in the baggage compartment.

1. Connect 28 volt power to rear of Guidance unit (Power Switch OFF).

*The telescope must be supported manually from the rear during steps 1-3.



*DO NOT TIGHTEN LOCKNUT COMPLETELY TO AVOID BINDING TELESCOPE LIMIT ARM AT LOW ELEVATION ANGLES.

Figure 7.— Assembly of Lear Jet telescope turnbuckle support.

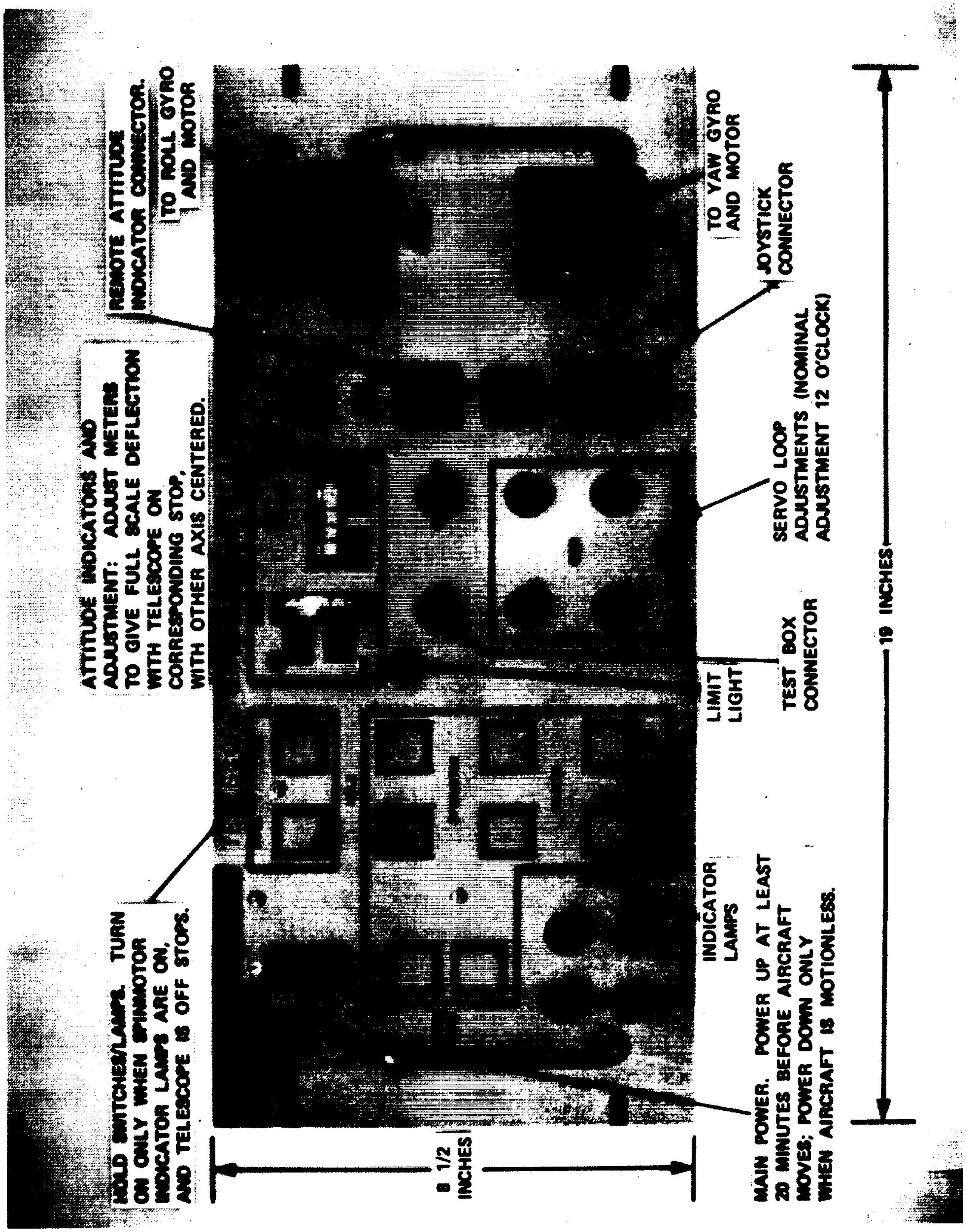


Figure 8.— Telescope stabilization electronics.

2. Mount Guidance Unit in rack or appropriate bracket with four 10-32 binding head screws, with washers under the heads.

3. Connect telescope cables to Telescope Stabilization Electronics. The roll and yaw outputs on the Guidance Unit are labelled on front panel, and color coded.

4. Connect Joy stick Box to Guidance Unit at connector labelled "Joy Stick."

5. Connect Pilot Indicator to connector labelled "Yaw Indicator."

C. Installing the Primary Mirror

Install the primary mirror from the rear of the telescope with the backplate removed. The front outside edge of the primary should rest against three 1-mm thick polyethylene pads glued to the shoulder in the telescope tube. It is essential that the pads be located at the same angular position as the tapped holes for the Primary Mirror Retention Screws (see figure 5). The telescope tube should be warmer than about 65° F to allow the primary mirror to be mounted without binding. Once the mirror is in place, the backplate can be installed; the Primary Mirror Retention Screws should be in the appropriate holes in the backplate. These screws (1) should have Nylon feet on the ends which bear on the mirror, (2) should turn freely in the threaded holes in the backplate, (3) should have lock nuts on the instrument side of the backplate, and (4) should be backed out of the backplate as far as possible so as not to bear on the mirror while the backplate is being bolted onto the telescope tube. Once the backplate is bolted in place, the Primary Mirror Retention Screws can be tightened to hold the mirror firmly against the pads which are between the front edge of the mirror and the shoulder in the telescope tube.

Since the pads are located opposite the screws, the forces exerted on the mirror tend only to compress the mirror at the edge and not to bend it. Care must be exercised to avoid damage to the mirror by tightening the screws too far. After the screws have been tightened, the lock nuts must be tightened against the backplate to prevent the screws from backing out.

D. Balancing the Telescope (see figure 9).

Ideally the telescope should be balanced so that it will remain in any orientation in which it is place. The telescope structure is unbalanced in roll due to the yaw torque motor mounted on the top of the gimbal ring, and in yaw due to the guide scope mounted on the right side of the tube. Counterbalances for these effects are supplied: weights on the bottom of the gimbal ring counterbalance the yaw torque motor, and weights on the telescope tube and backplate counterbalance the guide telescope. To complete the balancing job, the secondary mirror should be installed (as described in section III B), the instrument must be installed on the back plate, and weights added until the telescope balances: this will be possible for instruments weighing up to about 20 kg (45 lb) depending on the distance of the center of mass from the backplate. The maximum torque relative to the roll axis which can be balanced is about 6.78×10^8 dyne-cm (600 in.-lb).

In general the "balanced" telescope will correspond to one of the following configurations:

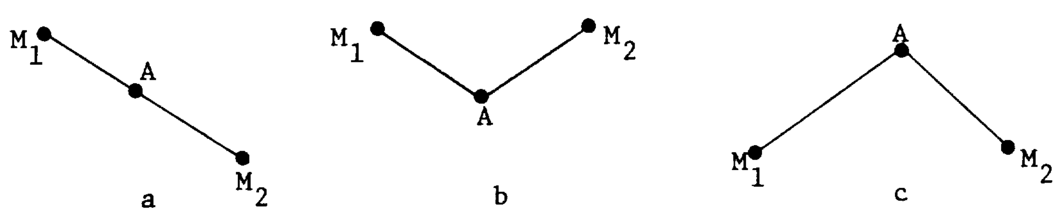


Figure 9.— Balance configurations.

Here M_1 and M_2 are unequal weights supported on unequal but rigid arms pivoted at an axis A. In configuration (a) the instrument is perfectly balanced, the arms being colinear; in configuration (b) one has unstable equilibrium, and configuration (c) corresponds to stable equilibrium. The counterweights should be distributed to approximate configuration (a) as nearly as possible. There is a 6.35 kg (14 lb) weight located on the bottom of the telescope tube 19 cm (7 1/2 in.) forward of the gimbal ring, which will help compensate the load of a heavy instrument (dewar) extending above the telescope axis. For light instruments this weight can be removed. The telescope/instrument combination is difficult to balance perfectly, but stable equilibrium is probably more desirable than unstable equilibrium. The torque motors can compensate an imbalance $\sim 3.38 \times 10^6$ dyne-cm (1/4 ft-lb) without serious reduction in tracking capability when the aircraft is flying through "smooth" air.

In flight it may be noticed that the telescope becomes unbalanced in roll and yaw. In roll, the usual effect is such that less weight (a pound or so) is required on the back plate to maintain balance. The balancing arrangement should permit easy removal of up to $\sim$1.5 kg (3 lb) of weight from the backplate to compensate for this effect. In yaw, the front end of the telescope may tend to go forward, and if so, a forward force can be applied to the rear fo the telescope with a bunje cord.

E. Completing the Installation

All cables must be secured and routed to avoid interference with the observers. A metal channel is supplied which allows cables to be routed across the cabin floor. All Cables should be securely mounted and attached to their respective connectors. Signal cables from the detector should not be routed near the telescope cables or the chopper drive cable.

Signal channel noise may, at times, be reduced by grounding the detector assembly to the airplane structure since a low resistance path may not exist through the telescope gimbals.

A flexible heating duct called the "blast tube" blows warm air on the guide scope window to prevent it from frosting. Be sure the blast tube is installed.

III. Telescope Setup and Adjustment Procedure

The procedure for setup and adjustment of the telescope for the desired optical characteristics is:

A. Select a secondary mirror.

B. Install the secondary mirror.

C. Check chopper alignment.

D. Set the chopper throw and alignment.

E. Focus the telescope.

F. Boresight.

III.A. Selecting the Secondary - see figure 10

Several secondary mirrors are available for use with the telescope. The choice of which secondary to use depends primarily on the back focal distance of the instrument. Let f be the distance of the detector aperture behind the backplate mounting surface. Then

$$Z_L = f + d \simeq f + 31 \text{ mm} \tag{1}$$

is the distance from the image plane to the primary vertex.

If D_s is the secondary mirror diameter and Z_s the distance between the vertices of the primary and secondary mirrors, then the equivalent f-number of the telescope is

$$f_e = \frac{Z_s+Z_L}{D_s} , \tag{2}$$

and the underfilled primary diameter is

$$D_{pu} = \frac{F_p D_s}{F_p-Z_s} , \tag{3}$$

where F_p is the focal length of the primary mirror. The equation for focus is

$$\frac{1}{F_p-Z_s} - \frac{1}{Z_s+Z_L} = \frac{2}{r_s} , \tag{4}$$

where r_s is the radius of curvature of the secondary mirror. Solving (4) for Z_s, one obtains

$$Z_s = \frac{1}{2} \left\{ F_p - Z_L - r_s + \left[r_s^{\,2} + (F_p + Z_L)^2 \right]^{1/2} \right\} \qquad (5)$$

If the primary is to be underfilled, then for each secondary mirror there is a maximum value of Z_s, Z_s^{MAX}, determined by (3), a corresponding minimum value of f_e, f_e^{MIN}, is determined by (2), and a minimum value of Z_L, Z_L^{MIN}, determined by (4). The values of Z_s^{MAX}, f_e^{MIN}, and Z_L^{MIN}, assuming D_{pu} = 300 mm are shown for the various secondaries in figure 10. Actually these values are somewhat extreme, since the effects of chopping and finite detector aperture will increase the telescope aperture used over that predicted by (2). The effect of an on-axis detector aperture of diameter a will be to increase D_{pu} by

$$\delta_1 \simeq \frac{a\, Z_s}{Z_s + Z_L} . \qquad (6)$$

A chopper throw of angle γ relative to the beam axis (total symmetric throw 2γ) will increase D_{pu} by

$$\delta_2 \lesssim \frac{Z_s F_p 2\gamma}{F_p - Z_s} .$$

Typically $\delta_1 + \delta_2 \lesssim 5$ mm.

To choose a secondary, one must first determine Z_L for his instrument from (1). Then from the list in figure 10 select a secondary such that $Z_L \gtrsim Z_L^{MIN}$. Where two or more secondaries can do the job, select the one which gives the f-number nearest the desired value. Using the parameters r_s and D_s for the selected secondary, find Z_s from (5). Use this to obtain f_e, D_{pu}, δ_1, and δ_2 from (2), (3), (6), and (7), respectively. The quantity $D_{pu} + \delta_1 + \delta_2$ should be less than about 300 mm, assuming the primary must be underfilled.

Image quality will depend on the chopper throw, the secondary used, and the back focal distance. Typically images are less than one millimeter in diameter and the best images are obtained for $Z_L \sim 80$ mm. A computer program for calculating the image quality for a given configuration is available.

III.B Installation of Secondary

The first step in installing the Secondary is to position the spider. The distance L between the spider and the end of the telescope barrel is calculated from $Z = Z_s - 314$ (mm) (see figs. 11 and 12). Once the distance L is calculated, the optimum spacer as shown in figure 13 is then chosen.

Once the spider has been mounted, the selected secondary should be mounted on the chopper. Two types of secondaries are used, aluminum type and silicon or cervit type.

The aluminum secondary is held on the Mirror Support by the special retainer Screw, as shown in figure 14. The Teflon Washer prevents the Secondary from distorting when the Screw is tightened. Do not tighten too much! About

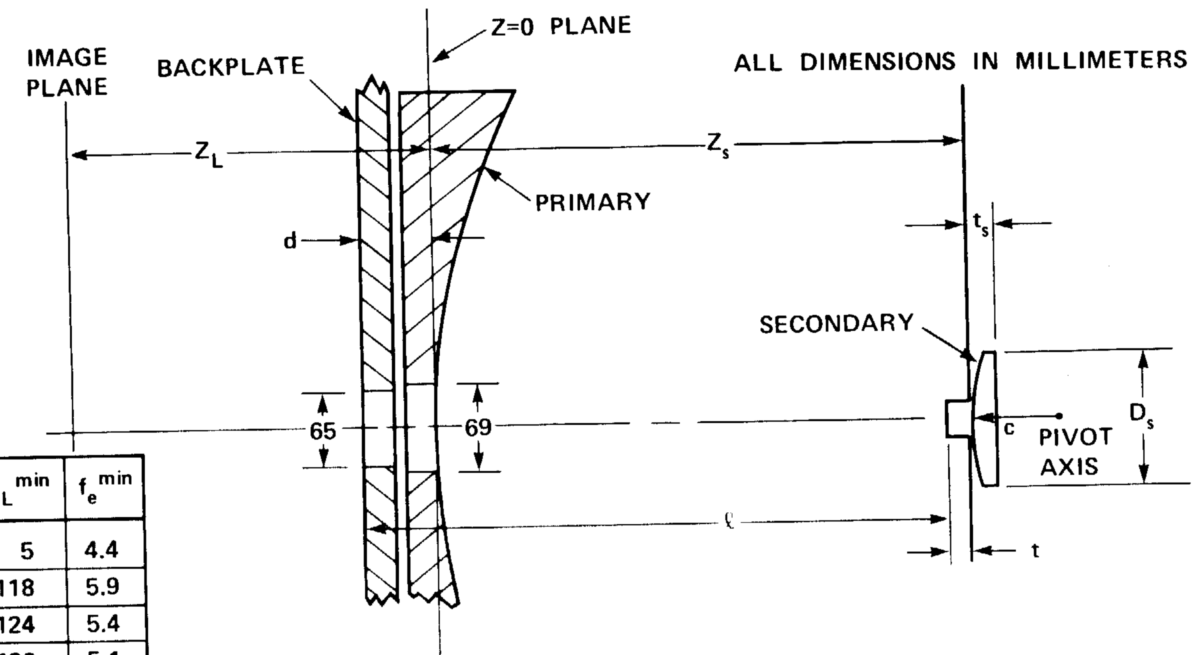
5 ft-lb is adequate. After the Screw is tight, secure it with the Lock Nut, using the special long-shank nut driver.

The silicon and cervit secondaries are permanently bonded to chopper mirror support. The special retainer screw is still used as an additional precaution.

F_p = PRIMARY FOCAL LENGTH = 460

r_s = SECONDARY RADIUS OF CURVATURE

ALL DIMENSIONS IN MILLIMETERS



SECONDARIES

MATERIAL	t_s	r_s	D_s	Z_s^{max}	Z_L^{min}	f_e^{min}
ALUMINUM	4.0	369	78	340	5	4.4
SILICON	7.3	325	78	340	118	5.9
SILICON	6.5	360	84	331	124	5.4
CERVIT	4.4	435	99	308	196	5.1
CERVIT	4.3	298	78	340	276	7.9
CERVIT	4.9	324	84	331	302	7.5

PHYSICAL LIMITATION: $290 \lesssim Z_s \lesssim 390$

$Z_s = \ell + t - d, \; d \cong 31 \;\; t \cong 7 \;\; c \cong 20$

EQUIVALENT F-NUMBER $f_e = \dfrac{Z_L + Z_s}{D_s}$

EQUATIONS FOR FOCUS

$$\frac{1}{F_p - Z_s} - \frac{1}{Z_s + Z_L} = \frac{2}{r_s},$$

OR,

$$Z_s = \tfrac{1}{2}\left\{F_p - Z_L - r_s + \left[r_s^2 + (F_p + Z_L)^2\right]^{1/2}\right\}$$

$$\frac{dZ_L}{dZ_s} = 1 + \left(\frac{Z_s + Z_L}{F_p - Z_s}\right)^2$$

RELATION BETWEEN CHOPPER THROW θ AND BEAM THROW γ:

$$\theta = \left(\frac{r_s}{r_s - c}\,\frac{D_p}{2\,D_s}\right)\gamma$$

c = SECONDARY PIVOT RADIUS

$D_{pu} = \dfrac{F_p}{F_p - Z_s} \times D_s$ = UNDERFILLED PRIMARY DIAMETER

Figure 10.— Lear Jet telescope optics information sheet.

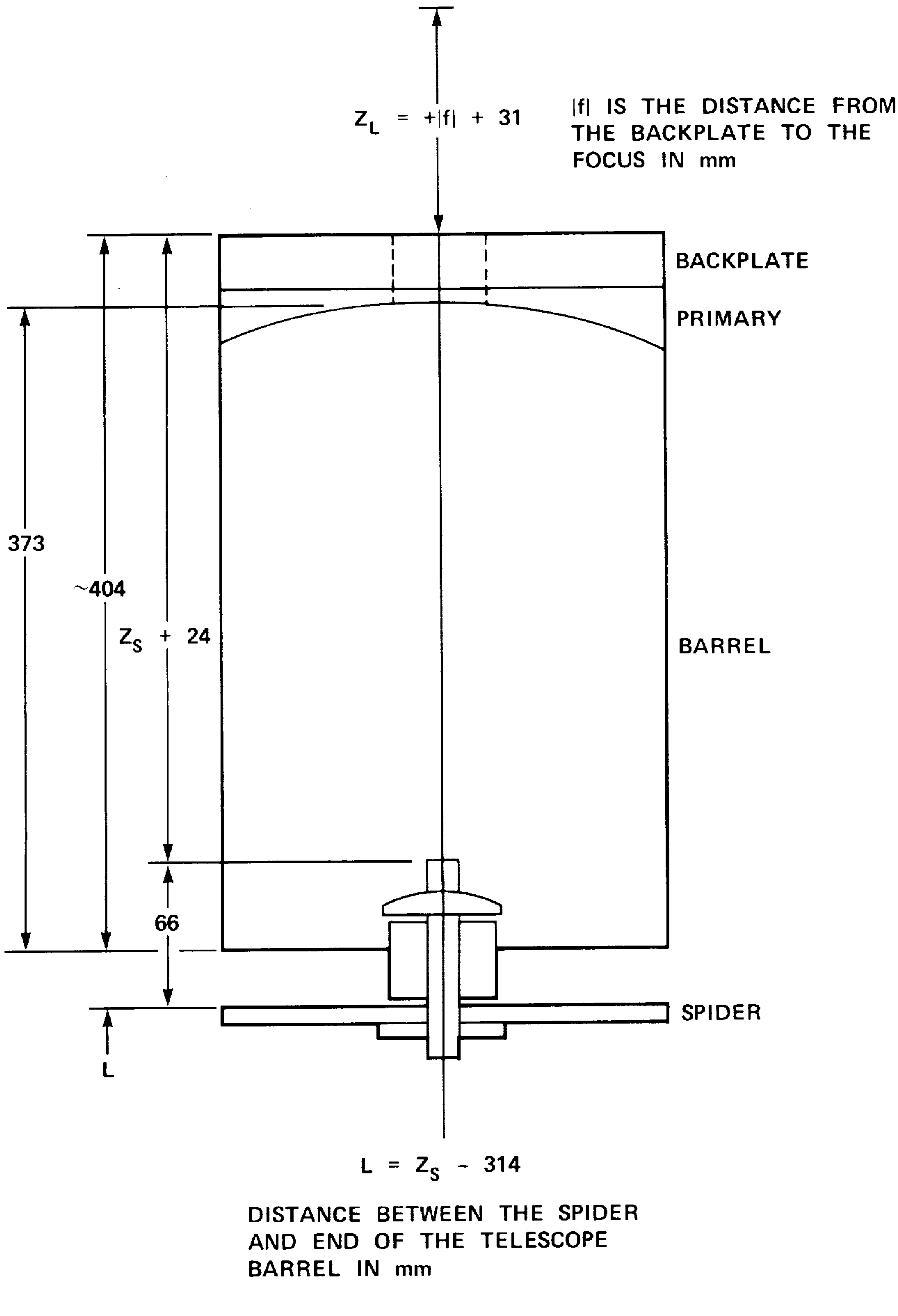


Figure 11.— Determination of spacer for Lear Jet telescope.

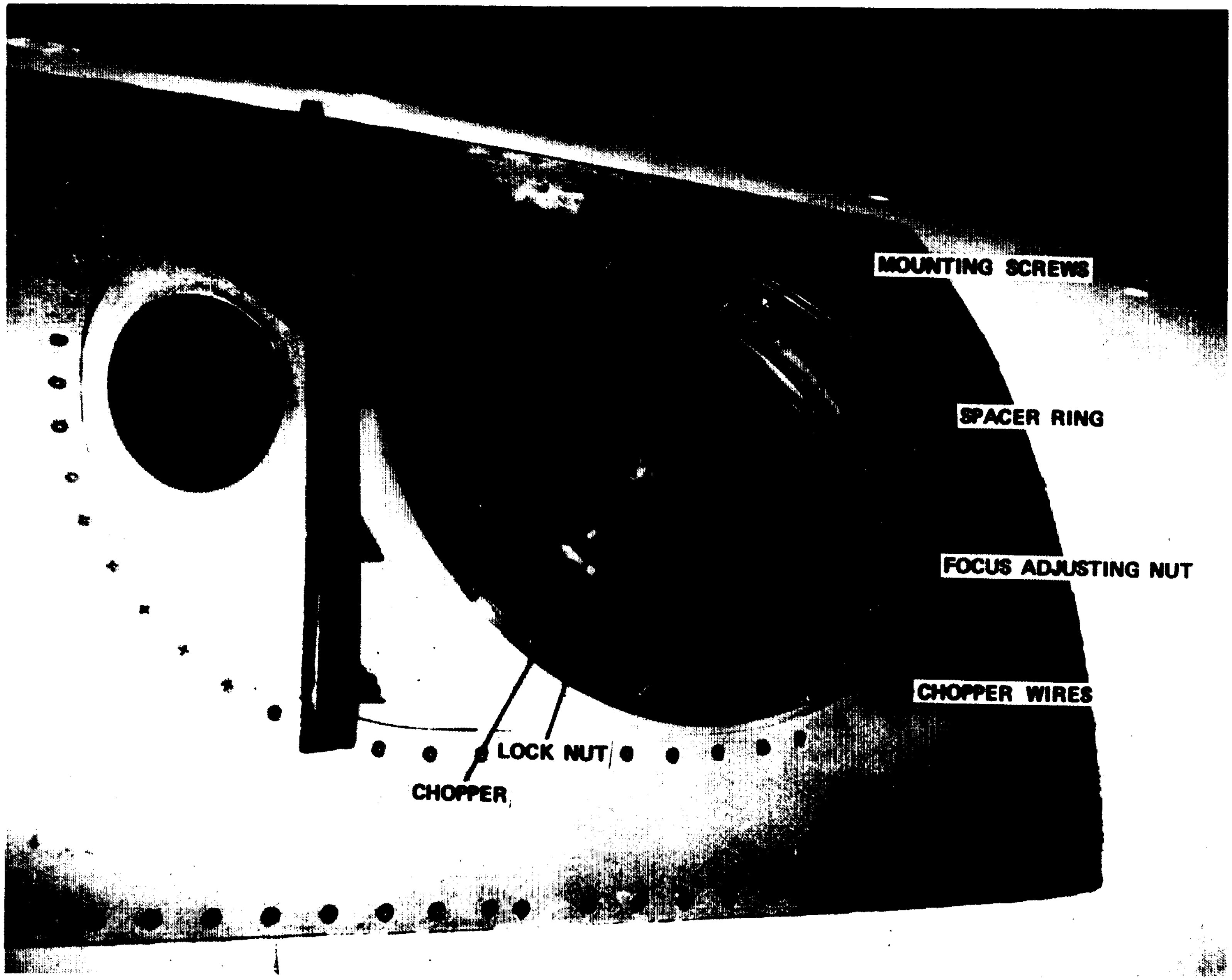
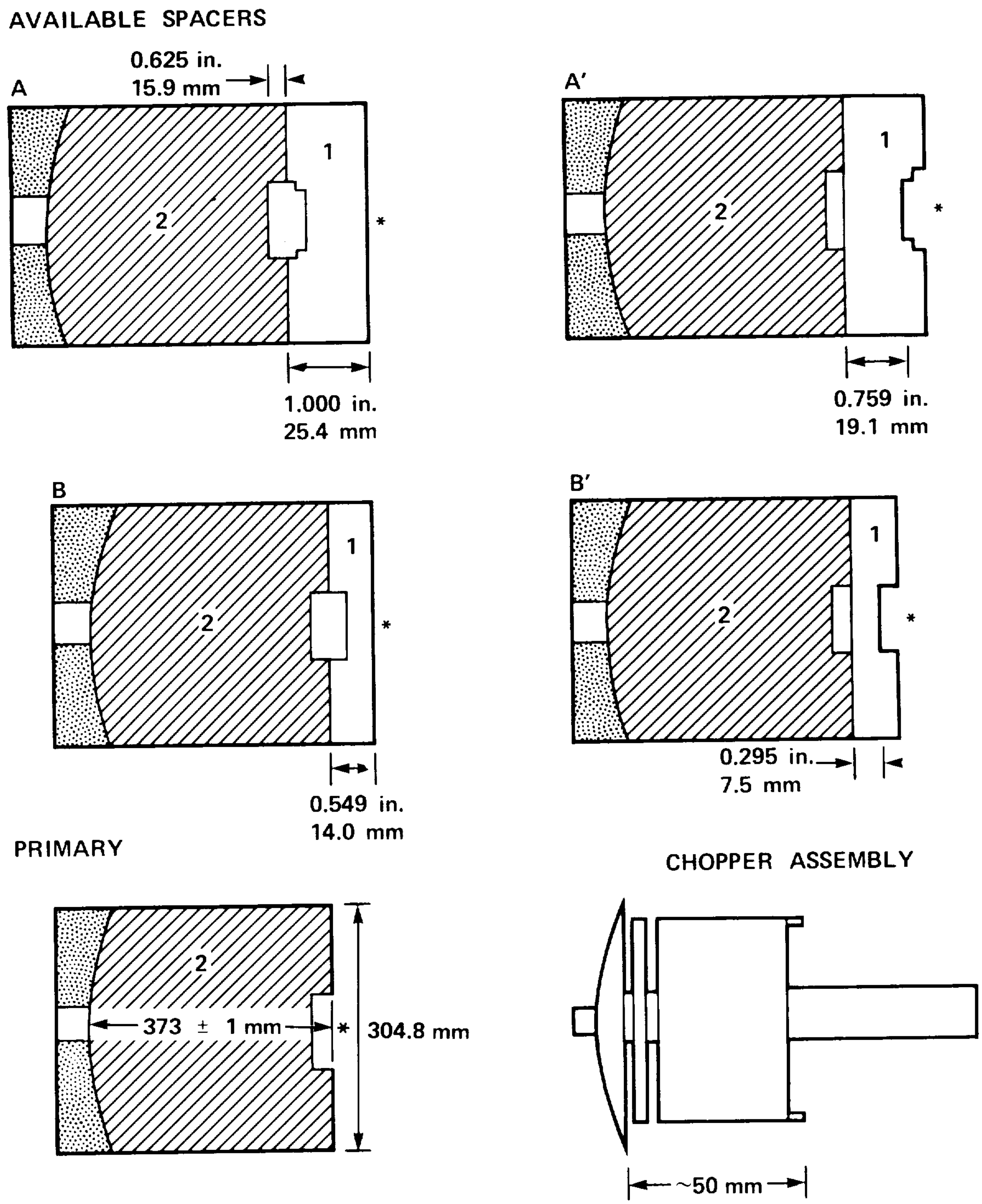


Figure 12.— Lear Jet telescope: exterior view showing oscillating secondary mechanism.



* SPIDER MOUNTS HERE
1 SPACER
2 TELESCOPE BARREL

THE DISTANCE BETWEEN THE SPIDER AND THE TELESCOPE BARREL MAY BE VARIED BY SELECTING ONE OF THE FIVE SPACER CONFIGURATIONS AS SHOWN IN THIS FIGURE.
THE SPACERS A,A′ AND B,B′ ARE THE SAME BUT INVERTED

Figure 13.— Available spacers.

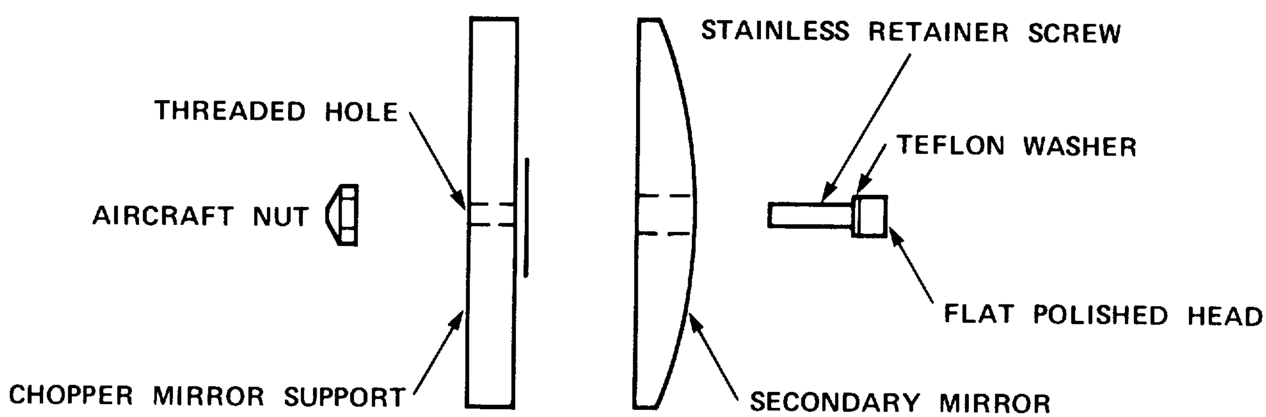


Figure 14.— Secondary mirror support.

III.C Checking Chopper Alignment

Viewed from about four feet behind the back plate, the secondary has the following appearance:

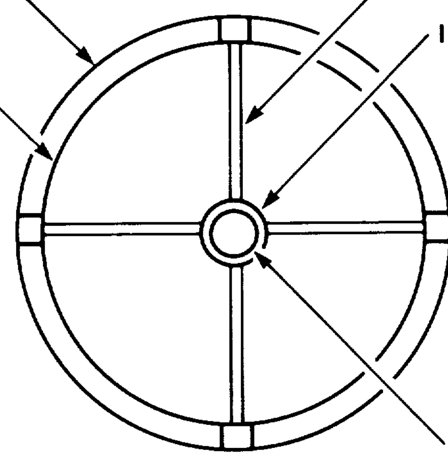


Figure 15.— View of secondary during optical adjustments.

Place your eye in such a position that the hole in the back plate and the edge of the secondary are concentric. When the assembly is aligned and when the chopper is in the middle of its throw the secondary retainer screw head and the image of the primary hole are also concentric. Moving the chopper from one beam to the other then moves the image of the hole in the primary symmetrically back and forth with respect to the screw head and moves the image of the vertical spider leg back and forth relative to the vertical spider leg. The chopper-driver circuit can be used to held the mirror in either position for extended periods in the "LOW" current drive position. Sensitivity of this method is about ± 1/2 arc min. Misalignments on the order of 1 arc min have not been found to affect offset signals appreciably in the 27-120 μ range. Adjustment of the Chopper Alignment is achieved by resetting the Chopper Throw Adjustment.

III.D Setting the Chopper Throw and Alignment

A gap in the chopper throw adjustment of X in thousandths of an inch results in a total chopper throw angle of 2Θ, where

$$2\Theta \cong 2.5 \text{ X arc min}$$

The relation between the chopper throw Θ and γ = beam throw in the sky (relative to the telescope axis) is given in the Optics Information Sheet (figure 10). There are several models of chopper presently used. The chopper adjustment procedure, figure 16, shows the mechanical details for adjusting the throw and alignment.

III.E Focusing the Telescope

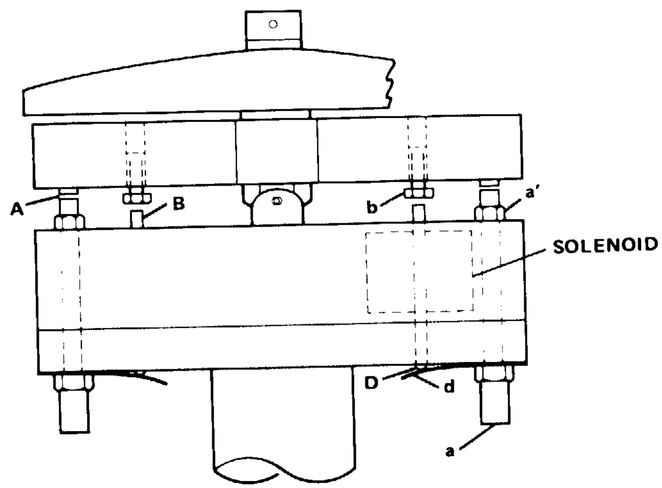
The focal plane of the telescope can be moved by manually moving the secondary mirror in and out. The position for the secondary, Z_s, may be calculated as indicated on the Optics Information sheet and in Section III A, equation 5. A measuring device can be used to obtain an approximate value for the primary-secondary distance. An adapter holding an eyepiece identical to the eyepiece of the spotting scope can be mounted on the back plate of the primary mirror. With the reticle at the desired position of the focal plane, the secondary mirror is moved in and out until the image of an object at infinity is in focus. The depth of focus is about $\pm$ 4 mm.

The focusing mechanism is depicted in figure 17. To focus the telescope, the Guide Screw and Lock Nut should be loosened, the four Locking Screws removed, and the Adjusting Nut rotated. When correct focus has been obtained, the Guide Screw, Locking Screws, and Lock Nut must be tightened and safety wired.

CHOPPER ADJUSTMENT PROCEDURE

TOOLS: LONG SHANK 7/16 in (NUT DRIVER)
7/32 & 1/4 in OPEN END WRENCHES

OUTLINE OF CHOPPER MECHANISM



There are two adjustments on each side, A: chopper-throw, and B: solenoid stop. After the desired throw is obtained, the solenoid stops must be adjusted so that the solenoid push-rods almost (but not quite) "bottom out". Some models of chopper do not have solenoid stop adjustments.

A. Chopper throw and alignment adjustment

1. Adjust the chopper throw to give the desired value and alignment using the adjustment screw a and lock-nut a'. The choppers which do not have a lock-nut a', have permanent nylon screw locking the adjustment screw a.

B. Solenoid push rod adjustment (some choppers do not have push rod adjustments)

1. Actuate one of the solenoid push-rods D by turning the chopper driver on "LOW" so as to close the gap A on the opposite side. Hold the mirror support to keep the gap A shut.

2. Loosen the stop-screw b until there is a gap B between the end of the stop screw and the end of the solenoid push-rod.

3. Keeping the throw-gap A closed and the opposite solenoid push-rod D depressed, advance the stop-screw b until it is $\gtrsim$ 1/4 turn beyond the position at which it contacts the end of the push-rod at B. This ensures that the push-rod is not "bottomed out".

4. Repeat B1-B3 on the other side

5. If chopper sounds erratic after this procedure, it is usually because one of the stop screws b needs to be advanced so as to further decrease the gap B.

Figure 16.— Chopper adjustment procedure.

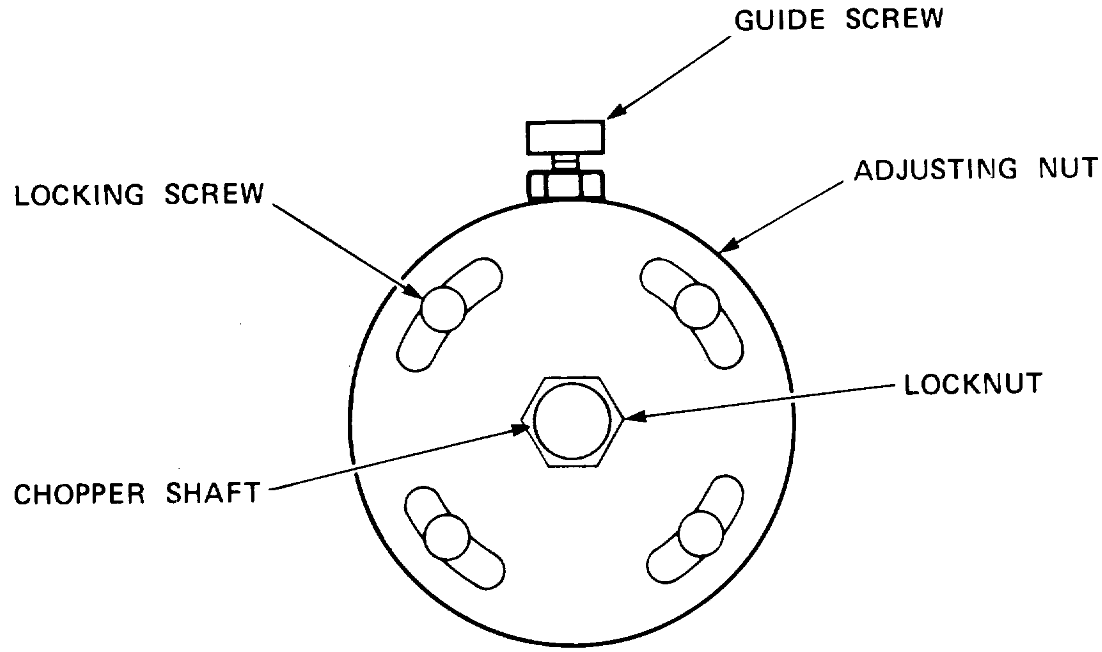


Figure 17.— Focusing mechanism seen from the rear.

The best object to focus on is a star. Alternatively, one can install a focusing adapter in the desired image plane. This adapter consists of a small light and screen which is mounted in the eyepiece adapter. By pointing the telescope at a first surface plane mirror, the image of the small light will be in focus on the screen when the telescope is properly focused.

III.F Boresighting the Guide Scope

This is best done using a distant point object (star) which can be detected with the detector and seen in the guide scope. Regrettably this often is not possible from the ground, so one arranges to view an optical image at a position corresponding to that of the detector. The eyepiece adapter which mounts on the back plate can be used, but it is usually more satisfactory to have a reticle which mounts at the detector position for the instrument being used. A distant light can be used as an object, but one should estimate the resulting parallax error. A boresight target is available in the hangar for use in inclement weather; to use this target, the main telescope is aimed at the light and the guide scope aimed at the cross. The separation between the axes of the guide scope and the main telescope is 32.4 cm (12 3/4 in.).

The boresight procedure consists of establishing a convenient correlation between the detector and guide-scope image fields. If a fixed object is used, the variable boresight shims on the telescope can be used to clamp the telescope in position. The guide scope Lock Adjustment is then loosened and the Roll and Yaw Adjustments turned until the image is located at the desired position on the guide-scope reticle. The image should be checked for both right and left beams. Nominally, the image for each beam is located near a convenient fiducial mark on the reticle.

IV. Guidance System Operation

A. Telescope Stabilization Electronics (see figure 8).

The guidance system will perform properly only when the telescope is balanced. The balancing procedure may be found under the section II.E Telescope Balance. Normally for sensor assemblies between 9 and 18 kg (20 and 40 lb), the "Gain" and "Phase" controls will be set to 12 o'clock. If the telescope response is either underdamped or overdamped, adjustment of the phase and gain controls is necessary.

The phase and gain controls vary the coefficients of the damping and restoring force terms for the second order differential equation describing the motion of the telescope. However, these controls are not independent of one another and one must vary them in an iterative process to find the settings for critical damping.

The gain control should be increased (clockwise) for a heavier instrumental package or decreased (counterclockwise) for a lighter instrumental package. Then the phase control should be varied until the telescope response is critically damped. It may be necessary to repeat this process several times.

1. Verify telescope balance.
2. Check that all cables are connected.
3. Check that the motion of the telescope is unrestricted.
4. Turn power on using "Power" switch. Both heater lights are on continously.
5. Wait approximately 20 min until both "SPIN MOTORS" indicators are lit (Heater lights cycling).

6. Hand guide telescope to desired object.

7. Press Roll and Yaw "HOLD" buttons. The "HOLD" switches are interlocked off unless the "SPINMOTOR" lights are on.

8. The telescope will hold until the object is beyond the limits of the telescope travel (LIMIT light on continuously, "POWER OUTPUT" lights on bright).

9. Press "HOLD" buttons turning off servo system (HOLD switch lights off).

The "POWER OUTPUT" lights monitor the torque motor amplifier outputs and should not be on bright continuously.

B. Joystick Assembly

The joystick assembly consists of a pressure sensitive rod for telescope pointing, roll and yaw drift controls, four switches controlling joystick and drift control sense, and remote "HOLD" and "CAGE" switches for the servo system.

The drift controls are set by observing an object while the telescope is in "HOLD". The controls are set to give no motion in the field-of-view. Once set, locking pins on the controls are set.

The Joystick, with no pressure applied, should cause no movement in the field-of-view. If motion is observed the drift controls require readjustment. With light pressure on the control stick the field-of-view will move slowly. The rate of movement is proportional to the pressure applied to the control stick.

C. Gyro Orientation

Each guidance gyroscope provides a voltage output to the servo system error amplifier proportional to the angular deflection about that gyroscope's sensitive axis. Angular deflections on the axes orthogonal to the sensitive axis produce no output. The definition of the sensitive axis of the gyroscope is shown in the figure 18. Note the two notches in the brass ring on the gyro. The notch located 90° from the cable defines one point on the sensitive axis. The second notch, opposite the cable, defines the normal to the sensitive axis. When the gyro is mounted on a gimballed surface the sensitive axis must be parallel to the axis of rotation of that gimbal. The gyro mounted on the back surface of the telescope is the yaw gyro. The roll gyro is mounted to the gimbal ring.

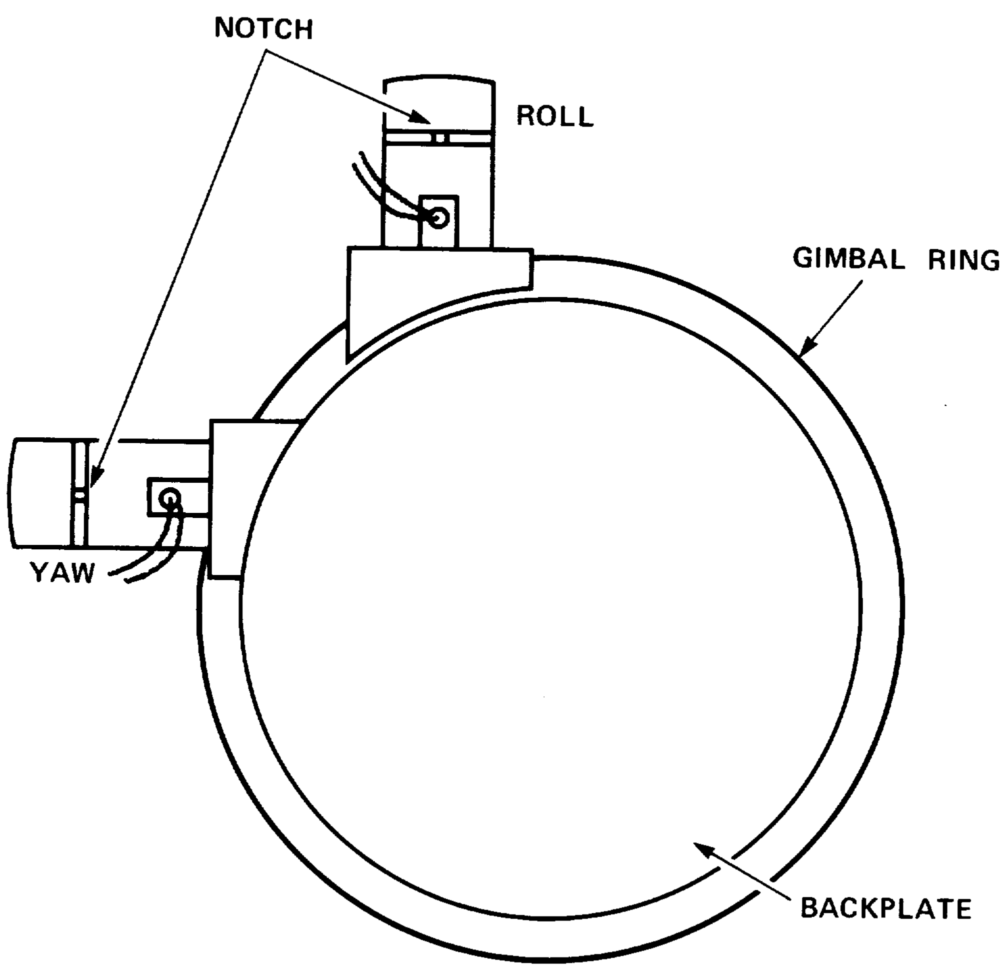


Figure 18.— Schematic of the sensitive gyro axes.

If cross-coupling (i.e., aircraft roll causing telescope yaw or conversely) occurs then the gimbal axes are not parallel to the gyroscope sensitive axes.

D. Telescope Attitude Indication

Potentiometers on the Torque Motors sense the attitude of the telescope relative to the roll and yaw limit positions. The attitude is indicated by meters on the front of the telescope stabilization package and remote meters on the umbilical, and can be calibrated by swinging the telescope from stop to stop using adjustments on the front panel. A limit light indicates when the telescope is near limiting positions.

The true and mean telescope elevations are given by indicators mounted on the telescope as shown in figure 3.

E. Test Box

The test box can be connected to the front of the Telescope Stabilization Electronics (see figure 8) to bring out the voltages from the Roll and Yaw power amplifiers and the error amplifier signals. A selection switch allows the various signals to be presented across a two terminal type GR connector. An oscilloscope or voltmeter can be used to monitor the voltages at the terminal posts. Due to the nature of the signals being monitored the measuring instrument must be floating. DO NOT GROUND EITHER TEST BOX OUTPUT.

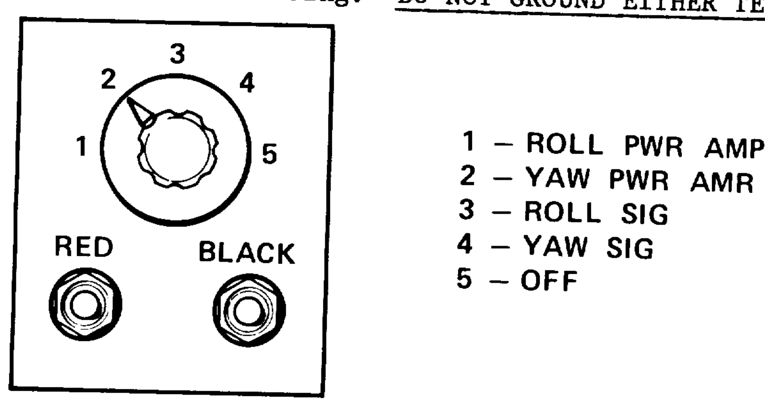


Figure 19.— Test box for the telescope stabilization electronics.

When the selection switch is in the PWR AMP position the voltage across the torque motor is monitored. If the telescope is balanced, and in HOLD, the voltage will be less than 0.5 volt. When a force is applied to the telescope this voltage will increase to approximately 24 volts with a polarity dependent on the direction of the force. The voltage may be used as an indication of balance. Weights should be adjusted to prevent the voltage from exceeding 2 to 3 volts in HOLD when the telescope is static. For proper operation the voltage should not contain ripple exceeding 2 to 3 volts nor should it show evidence of oscillation.

When the selection switch is in the SIG position the error amplifier output is monitored. This voltage, in either the HOLD or CAGE mode should be less than 0.5 volt when the telescope is static. For proper operation the output of the error amplifier should show no oscillations nor excessive DC offset (less than 0.05 volt). The voltage output from the error amplifier should not change when the gain control or phase control on the front panel of the Guidance Unit is changed.

F. Trouble Shooting

A Telescope Guidance Servo System Manual with a detailed description of the electronics is available for finding and repairing electronics malfunctions.

V. Airborne Operation

A. Remarks

A checklist for a typical infrared astronomy mission aboard the Lear Jet is given here as an example of the procedure which, with minor modifications, should be followed by most investigators. Many of the items on the list are related to safety and operation of the experimenters' equipment. However the sequence shown indicates how the operation of the telescope is integrated into a normal investigation.

In addition, a trouble-shooting list which covers the most common problems encountered during a flight is included. Again, many of the items do not concern the telescope. Experience has shown that such a list is often helpful in sorting out problems which arise during a Lear Jet observation.

These lists are presented as guidelines only. Experimenters often generate check lists appropriate to their particular investigation. However, the items on the lists presented here which are associated with the telescope and safety should be included in any such list.

B. Check List

T - 6 hours

1. Fuel aircraft, fill oxygen tanks
2. Check inventory: tools, strip chart paper & ink, magnetic tape, finding chart, flight plan
3. Get personnel to check out oxygen masks

T - 3 hours

Final fill with liquid He, start pump-down in airplane

T - 1 hour

1. Check tape and strip chart calibration
2. Check chopper and turn off
3. Check intercom to tape recorder, using headsets
4. Turn on telescope electronics to start gyro warmup
5. Check adjustment of attitude meters
6. Check preamp gain, batteries
7. Record D.C. voltage on detector

T - 1/2 hour

1. Turn on system except chopper
2. Check stabilization on "HOLD", and adjust drift if $\gtrsim$ 10 arc min/min
3. Cage gyros (turn off HOLD lights)
4. Record noise out of preamp and phase-lock amplifier with chopper off and on
5. Check hand signal
6. Check phase, set gain to measure noise
7. Spectrometer on starting position
8. Check safety wires on chopper, spider, and telescope
9. Check that racks are secure

10. Adjust Elevation Angle Adapter to position telescope for initial observing elevation angle

11. Check that there is no loose equipment or tools

12. Check availability of spare masks

T - 1/4 hour

1. Start strip chart on slow speed
2. Chopper on "Low"
3. Put on and test oxygen masks and head sets. (Observer install ear phone)
4. Fasten seat belts
5. Review emergency procedures list provided by pilots

Takeoff

1. Gyros on and caged
2. Electonics on
3. Strip chart running, slow speed
4. Hang on to telescope to prevent bumping

T + 5 min

Ascent

1. Request pilot permission to take off seat belts
2. Check proper operation of masks periodically
3. Avoid pointing telescope at sun
4. Turn chopper on "high"
5. Adjust telescope balance (remove typically $\sim$ 1 kg or 2 lb)
6. Check blast tube output on guidescope window
7. Record temperature, altitude, Mach No. and detector noise periodically, say every km or 3000 ft.
8. Check and record cabin pressure differential ($\sim$4 psi) detector pressure, D.C. voltage on detector

9. Check drift in telescope by guiding on a star

10. Check yaw and roll meter calibration for pilots

T + 30 min On course

1. Request pilot turn off beacon
2. Start recorder
3. Acquire source in finder telescope
4. Request pilot to orient aircraft to zero yaw meter
5. Center object in yaw <u>and</u> tell pilots to follow yaw meter
6. Put gyros on hold
7. Reacquire source and <u>check</u> <u>boresight</u> (left and right)
8. Adjust gain and offset, check phase
9. Hold on object in right beam and left beam to check pointing and stability for duration of a scan
10. Adjust mean telescope elevation to keep object centered in roll
11. Cage gyros when telescope has been on stops more than 10 sec

Between objects/end of observations

1. Put gyros on cage
2. Watch sun position
3. Record altitude, temperature, Mach No., cabin pressure
4. Record detector pressure, noise, & D.C. voltage
5. Turn off recorder
6. Turn system power off <u>except</u> <u>GYROS</u>
7. Valve off detector

8. Watch detector pressure

9. Secure all loose equipment

10. Fasten seat belts

11. Write summary note describing flight

Landing

1. Hold telescope to prevent BUMPING!

2. Turn off gyro power only after aircraft has stopped moving

Post flight

1. Stay with dewar until up to atmosphere

2. Complete flight summary note

3. Cover telescope

Trouble shooting

1. Object not in guidescope field-of-view (FOV)

   a. Focus guidescope. (If daytime, bank aircraft and focus on ground.)

   b. Scan guidescope FOV with gimbals (1) centered, (2) full right, (3) full left, (4) full up, (5) full down

   c. Request pilot verification of adherence to flight plan

   d. After 5 minutes on published heading, request 3° right turn, repeat b; then 6° left turn, repeat b

2. No signal from object

   a. Thump bias box or dewar to produce microphonics

b. Ground preamp input to see if noise changes

c. Check preamp settings

d. Check detector pressure

e. Measure detector bias voltage

f. Check phase lock: gain, phase, time constant

g. Verify chopper is operating

h. Search vicinity of nominal boresight

3. Excessive noise:

a. Check noise with preamp input shorted

b. Check noise with detector bias off

c. Check noise with chopper off

d. Check noise with gyros off

e. Try another chopper speed

f. Check for correct phase, time constant on phase lock

g. Try damping telescope vibrations with hand

h. Try grounding preamp, phase-lock input, etc. with clip lead

4. Telescope sticks in gimbals:

a. Check cabin pressure differential is 4 psi

b. Look for mechanical restrictions near underside of telescope

5. Telescope elevation adapter sticks

a. DO NOT FORCE TURNBUCKLE!

b. Check boot; if stuck in air seal, back off turnbuckle and try to remove boot from air seal manually